TRANSACTIONS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. IX.

JANUARY TO DECEMBER, 1880.

NEW YORK:
PUBLISHED BY THE SOCIETY.

1880.

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CONTENTS.

PAPERS.

NO.	MONTH.		PAGE.
.....	(*January.*)	Discussion on Inter-Oceanic Canal Projects :	
		By WALTON W. EVANS	1
		By FREDERICK M. KELLEY	21
		By CHARLES A. SWEET	25
		By JOHN C. CAMPBELL	28
		By CHARLES D. WARD	34
		By NATHAN APPLETON	36
		By S. F. SHELBOURNE	37
		By MAX E. SCHMIDT	39
		By THOMAS J. LONG	42
		By EDWARD P. NORTH	45
.....	(*February.*)	Discussion on Inter-Oceanic Canal Projects :	
		By ASHBEL WELCH	47
		By JULIUS W. ADAMS	59
.....	(*March.*)	Discussion on Inter-Oceanic Canal Projects :	
		By O. CHANUTE	87
		By FERDINAND DE LESSEPS	89
		By JUSTIN DIRKS	95
		By V. DAUZATS	97
CLXXXIX.	(*do.*)	The Engineering Problems Involved in the Proposed Improvement of the Erie Canal by Increasing the Depth of the Channel One Foot.	
		Presented June 17th, 1879.—E. SWEET, JR	99
.....	(*do.*)	Discussions at the Eleventh Annual Convention :	
		On Paper CLXV. Cushioning the Reciprocating Parts of Steam Engines :	
		By CHARLES E. EMERY	111
		By JOHN W. HILL	115

70390

NO.	MONTH.		PAGE.
.....	(*April.*)	Discussion on Inter-Oceanic Canal Projects :	
		By JUSTIN DIRKS	117
		By A. COUVREUX, fils	124
		By ASHBEL WELCH	132
		By WILLIAM E. MERRILL	142
		By CHARLES MACDONALD	142
		By ASHBEL WELCH	148
		By THOMAS C. CLARKE	159
CXC.	(*do.*)	Progress of Work at the East River Bridge.	
		Presented June 17th, 1879.—FRANCIS COLLINGWOOD	162
CXCI.	(*May.*)	On the Variation due to Orthogonal Strains in the Elastic Limit in Metals, and its Practical Value and More Important Applications.	
		Read April 7th, 1880.—ROBERT H. THURSTON	173
CXCII.	(*do.*)	Experiments with Appliances for Testing Cement.	
		Presented June 17th, 1879.—ALFRED NOBLE	186
.....	(*do.*)	Discussions at the Eleventh Annual Convention :	
		On Paper CXCII. Experiments with Appliances for Testing Cement :	
		By DON J. WHITTEMORE	199
CXCIII.	(*do.*)	Design and Construction Table for Egg-shaped Sewers.	
		Presented June 17th, 1879.—CYRUS G. FORCE, JR	202
CXCIV.	(*do.*)	The Preservation of Timber.	
		Read October 15th, 1879.—JOSEPH W. PUTNAM	206
CXCV.	(*June.*)	Annual Address, 1880.– Engineering Progress in the United States.	
		Read at the Twelfth Annual Convention May 25th, 1880.—O. CHANUTE	217
CXCVI.	(*July.*)	The Hudson River Tunnel.	
		Presented May 25th, 1880.—ARTHUR SPIELMANN and CHARLES B. BRUSH	259
.....	(*do.*)	Discussions at the Twelfth Annual Convention.	
		On Paper CXCVI. The Hudson River Tunnel :	
		By ASHBEL WELCH	273
		By E. S. CHESBROUGH	273
		By JAMES B. EADS	273
		By JAMES B. FRANCIS	273
		By CHARLES B. BRUSH	273
		By WILLIAM R. HUTTON	276
CXCVII.	(*do.*)	American Natural Cement.	
		Read May 25th, 1880.—F. O. NORTON	278
.....	(*do.*)	Discussion at the Twelfth Annual Convention.	
		On Paper CLXXXIX. The Engineering Problems involved in the Proposed Improvement of the Erie Canal by Increasing the Depth of its Channel one foot.	
		By ASHBEL WELCH	287
CXCVIII.	(*do.*)	Notes on the South Pass Jetties.	
		Read May 25th, 1880.—MAX E. SCHMIDT	290

NO.	MONTH.		PAGE.
.....	*July*	Discussion at the Twelfth Annual Convention :	
		On Paper CXCVIII. Notes on the South Pass Jetties :	
		By JAMES B. EADS	291
CXCIX.	(*August.*)	Ship Canal Locks Calculated for Operation by Steam.	
		Read May 25th, 1880.—ASHBEL WELCH	293
CC.	(*do.*)	Discussion on The Use of Steel for Bridges.—WILLIAM SELLERS	315
CCI.	(*do.*)	Remarks on the Causes of Fall of the Western Arched Approach to the South Street Bridge, Philadelphia.—JOHN G. BARNARD	319
CCII.	(*do.*)	Note on Kutters Diagram.—CHARLES H. SWAN	326
CCIII.	(*September.*)	Tensile Tests of Cement and an Appliance for more Accurate Determinations.	
		Read May 25th, 1880.—DON J. WHITTEMORE	329
.....	(*do.*)	Discussions at the Twelfth Annual Convention :	
		On Paper CCIII. Tensile Tests of Cement and an Appliance for more Accurate Determinations. And on Paper CXCVII. American Natural Cements :	
		By WILLIAM P. SHINN	341
		By D. J. WHITTEMORE	341
		By MARTIN CORYELL	341
		By ASHBEL WELCH	342
		By JAMES B. FRANCIS	342
		By JAMES B. EADS	342
		By JAMES H. HARLOW	344
		By MAX E. SCHMIDT	345
		By F. O. NORTON	345
		By E. S. CHESBROUGH	345
		By JOHN BOGART	346
		By WILLIAM R. HUTTON	346
CCIV.	(*do.*)	Waterproof Coverings :	
		Read May 25th, 1880.—FRANCIS COLLINGWOOD	348
.....	(*do.*)	Discussions at Twelfth Annual Convention :	
		On Paper CCIV. Waterproof Coverings :	
		By EDWARD P. NORTH	351
		By FRANCIS COLLINGWOOD	352
.....	(*do.*)	Discussion on Paper CLXXXI. Flexure and Transverse Resistance of Beams :	
		By DE VOLSON WOOD	353
.....	(*do.*)	Discussion on Paper CXCI. On the Variation Due to Orthogonal Strains in the Elastic Limit in Metals :	
		By ROBERT BRIGGS	362
CCV.	(*October.*)	The Location of the Chimbote Tunnels :	
		Read May 25th, 1880.—O. F. NICHOLS	365
CCVI.	(*do.*)	Practical Consequences of Variation of the Wet Section of Rivers under General and Special Conditions :	
		Read May 25th, 1880.—ROBERT E. MCMATH	377

NO.	MONTH.		PAGE.
CCVII.	*October.*	Wind Pressure against Bridges :	
		Read May 25th, 1880.—ASHBEL WELCH.....	391
.....	(*do.*)	Discussions at Twelfth Annual Convention :	
		On Paper CCVII. Wind Pressure against Bridges :	
		By C. SHALER SMITH.....	393
		By THEODORE COOPER.....	393
		By JAMES B. EADS.....	395
		By C. SHALER SMITH...	396
		By ROBERT BRIGGS.....	397
CCVIII.	(*do.*)	Cheap Transportation *versus* Rapid Transit and Delivery.	
		Presented May 25th, 1880, and read June 16th, 1880.—MARTIN CORYELL.....	401
CCIX.	(*do.*)	The Crippling Strength of Wrought Iron Columns.	
		Read May 25th, 1880.—C. L. GATES.....	407
CCX.	(*November.*)	Web Strains in Simple Trusses with Parallel or Inclined Booms.	
		Read May 25th, 1880.—E. SWEET, JR.....	415
CCXI.	(*do.*)	Discussion upon Inter-Oceanic Canal Projects ; also, additional Information obtained by Recent Surveys in Nicaragua.	
		Read September 16th and October 6th, 1880.—A. G. MENOCAL.....	429
CCXII.	(*December.*)	The Strength of Wrought Iron Columns.	
		Read September 1st, 1880.—G. BOUSCAREN.....	447
CCXIII.	(*do.*)	The Improvement of the Harbor of Quebec.	
		Presented May 25th, and read September 1st, 1880.—J. VINCENT BROWNE.....	455

ILLUSTRATIONS.

PLATE.	MONTH.		PAPER.	PAGE.
I.	(*February.*)	Chart showing Routes from the Atlantic to the Pacific, by the Gulf of Mexico and the Caribbean Sea, accompanying discussion by Julius W. Adams		86
.....	(*May.*)	Fac-simile Autographic Strain Diagrams	CXCI.	181
II.	(*do.*)	Moulds, Clutches and Mixing Box for Testing Cements	CXCII.	188
III.	(*do.*)	Briquette and Cup Clutch for Testing Cement	CXCII.	200
IV.	(*do.*)	Combined Clutch and Mould for Testing Cement.	CXCII.	200
V.	(*do.*)	Section and Details for Egg-shaped Sewers	CXCIII.	204
.....	(*July.*)	Location of Shaft, Hudson River Tunnel	CXCVI.	262
.....	(*do.*)	End View of Air Lock, Hudson River Tunnel	CXCVI.	265
VI.	(*do.*)	Section of Hudson River Tunnel, when completed	CXCVI.	265
VII.	(*do.*)	Section of Hudson River Tunnel, in progress	CXCVI.	269
VIII.	(*do.*)	Shaft and Tunnel, Hudson River Tunnel	CXCVI.	272
IX.	(*do.*)	Curves of Tensile Strength of American Cement	CXCVII.	282
.....	(*do.*)	Metal Mould for Cement Briquettes	CXCVII.	282
.....	(*do.*)	Wood Mould for Cement Briquettes	CXCVII.	283
X.	(*do.*)	Curves of Tensile Strength of Portland Cement Mortars	CXCVII.	284
XI.	(*do.*)	Curves of Tensile Strength of American and Portland Cement Mortars	CXCVII.	286
XII.	(*August.*)	Ground Plan, Ship Canal Lock	CXCIX.	298
XIII.	(*do.*)	Platform, Ship Canal Lock	CXCIX.	300
XIV.	(*do.*)	Section, Ship Canal Lock	CXCIX.	302
XV.	(*do.*)	Section, Ship Canal Lock	CXCIX.	304
XVI.	(*do.*)	Travelling Apparatus, Ship Canal Lock	CXCIX.	308
.....	(*September.*)	Hollow Briquette	CCIII.	339
XVII.	(*do.*)	Briquette and Gimbal Clutch for ascertaining Tensile Strength of Cements	CCIII.	347
XVIII.	(*do.*)	Press and Flask for Moulding Briquette	CCIII.	347

PLATE.	MONTH.		PAPER.	PAGE.
XIX.	(*October.*)	Location of Chimbote Tunnels	CCV.	372
.....	(*do.*)	Illustrating Location of Chimbote Tunnels	CCV.	375
XX.	(*do.*)	Details of Location of Chimbote Tunnels	CCV.	376
XXI.	(*do.*)	Variation of Wet Section of Rivers	CCVI.	390
.....	(*do.*)	Sections of Wrought Iron Columns	CCIX.	408
XXII.	(*do.*)	Ultimate Crippling Strength of Wrought Iron Colums	CCIX.	412
XXIII.	(*do.*)	Safe Crippling Strains on Wrought Iron Columns.	CCIX.	414
XXIV.	(*November.*)	Strains in Trusses	CCX.	422
XXV.	(*do.*)	do. do. do.	CCX.	426
XXVI.	(*do.*)	do. do. do.	CCX.	428
XXVII.	(*do.*)	Map of Proposed Canal Routes between Nicaragua Lake and the Pacific Ocean	CCXI.	442
XXVIII.	(*do.*)	Profiles between Nicaragua Lake and the Pacific Ocean	CCXI.	444
XXIX.	(*December.*)	Apparatus to measure Compression and Extension of Wrought Iron Columns and Tie-Bars under Strain	CCXII.	449
XXX.	(*do.*)	Plate showing Improvements of Harbor of Quebec.	CCXIII.	456
XXXI.	(*do.*)	do. do. do. do.	CCXIII.	456
XXXII.	(*do.*)	do. do. do. do.	CCXIII.	458
XXXIII.	(*do.*)	do. do. do. do.	CCXIII.	458
XXXIV.	(*do.*)	do. do. do. do.	CCXIII.	460
XXXV.	(*do.*)	do. do. do. do.	CCXIII.	460
XXXVI.	(*do.*)	do. do. do. do.	CCXIII.	462
XXXVII.	(*do.*)	do. do. do. do.	CCXIII.	462
XXXVIII.	(*do.*)	do. do. do. do.	CCXIII.	462
XXXIX.	(*do.*)	do. do. do. do.	CCXIII.	462

ERRATA.

Page 20, third line from bottom: instead of fifteen *metres* to the mile, read fifteen inches to the mile.

Page 327. Formula at bottom of page should read :

$$x\,y = -bl \text{ (a constant) (11).}$$

Page 352, seventh line, for *best* absorbent, read least absorbent

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(Vol. IX.—January, 1880.)

INTER-OCEANIC CANAL PROJECTS *

DISCUSSIONS

By WALTON W. EVANS, FREDERICK M. KELLEY, CHARLES A. SWEET, JOHN C. CAMPBELL, CHARLES D. WARD, N. APPLETON, S. F. SHELBOURNE, MAX E. SCHMIDT, THOMAS J. LONG and EDWARD P. NORTH.

Discussion by WALTON W. EVANS.

I beg to offer a few remarks in discussion of Mr. Menocal's paper on the much-vexed project of the Inter-Oceanic Canal. I wish to give, first, my reasons for venturing an opinion :

1st. I have served for seven years as an engineer in the construction of canals.

2d. I have had an experience in the construction of public works of over forty-two years.

3d. I have crossed the Isthmus many times—partly by foot, by mule, by canal, and by rail.

4th. I have been detained on the Isthmus for weeks—by rains, revolutions, and want of transportation—before the railway was built.

*Inter-Oceanic Canal Projects. A. G. MENOCAL, No. CLXXXVIII., Vol. VIII., page 311 (November, 1879.)

5th. I have witnessed the heavens open their flood-gates, and seen the terrible washings the railway was subjected to.

6th. I have lived in earthquake countries for eleven years, and have witnessed the convulsions of Nature on the Isthmus as well as in Peru and Chile.

7th. I have, for over thirty years, made a study of this most interesting problem of cutting a canal for the largest ships through the narrow strip that divides North from South America.

8th. And I have read with care most of the public documents published in reference to it, and am clearly of the opinion that the "San Blas" route for a sea-level canal is far preferable to the Nicaragua route, with locks, or any other route ever reported on.

I beg to present some axioms in reference to this great problem:

1st. A canal thirty miles long is preferable to one a hundred and eighty-one and one-quarter miles long.

2d. A canal without locks is preferable to one with locks.

3d. A canal that has good harbors at its *termini* is preferable to one with no harbor at either end.

4th. A canal built in a healthy region is preferable to one in an unhealthy region.

5th. A canal that can be navigated in ten hours is better than one requiring one hundred hours.

6th. A canal that will call for very small repairs is preferable to one requiring immense repairs.

7th. A canal that has a small "water-shed," but a sure supply of water, is preferable to a canal having a great "water-shed."

8th. A canal that is not on a line of drainage is preferable to one on a line of drainage.

9th. A canal that can pass a ship of any length is preferable to one that limits the length to far below that of many existing ships.

10th. A canal that is virtually a straight line is preferable to one with many curves, some of them very objectionable.

I have read with care Mr. Menocal's clever paper, and beg to take issue with him on some points. He starts off with the assertion that the matter is narrowed down to two routes—the Panama and the Nicaragua. I should have been better satisfied if he had said the San Blas and the Nicaragua, for I look on the Panama route for a sea-level canal as simply ridiculous. I intimated the same,

but with less forcible words, to Count Ferdinand de Lesseps, in Paris. After many years of study of this matter, and after for a time believing in the Nicaragua route as the proper one, I came to the conclusion that the San-Blas route had many features in its favor that placed it far in advance of all others. I refer to the foregoing axioms for those features. I beg to say a word in defense of Count Lesseps. I have an impression that he is thoroughly honest, and find that is the opinion of all my friends in Paris who know him well. I think he was, in the conducting of the Congress influenced by men, who hoped to grow rich through the use of his name. He will soon see the error he has made when he reaches the Isthmus, and is made acquainted with the terrible destruction of the late floods. He said to me in Paris: "There is one point in this matter we must observe: wherever the canal is built *it must be a sea level canal.*" In this I fully agree with him; and I will add one more important engineering feature: it must not be built on any line of drainage, or across any line of drainage. What we require —what the world requires—is a perfectly reliable canal, that cannot by any accident run itself dry; that is perfectly secure against the accidents that can occur and do occur to all canals depending on dams and locks as working features, no matter how well and costly they may be built; if we cannot give the trade of the world such a canal we had better give it none.

I would not propose to run the San-Blas canal into the Rio Bayano, but turn that river off into the Bay of Panama by a cut made expressly for it; this could not be done for the Chagres River, except at an expense of many millions. It is proposed to build the Nicaragua Canal in the Valley of the San Juan, and in close contact with the river for many miles. I would suggest to the advocates of that route, and to the capitalists who I am told stand ready and eager to put their money in it, to first visit the Valley of the Lehigh, in Pennsylvania, and view the ruins of what was, within my recollection, a canal that received the praise and admiration of everybody; it was built by skilled engineers; the money furnished by the most careful and long-headed Quakers of Philadelphia; it had locks of thirty feet lift, the greatest ever put on a canal; the water-shed of the Lehigh is very insignificant; all the owners slept, no doubt, quietly in the possession of what they supposed to be a very safe investment; but a storm came—a flood was the result; this little lamb-like river became a great, fierce tiger, bent

on destruction; a weak point was found in the upper dam, the tiger poked his nose in it; a little leak was started, and away went the whole structure; with it went every dam and lock on the whole river, and hardly left a wreck behind; no one ever had the courage to rebuild that canal. There are many among us that recollect the destruction of the Croton River Dam; placed at the initial point of the Croton Aqueduct, it was built under the plans and direction of that Nestor in American engineering, John B. Jervis; he was an old and skilled canal engineer. Who have we at the present day who is his superior? That dam was built on rock, where the best of materials and skilled workmen were to be had in profusion; but it went—carrying havoc in its course –and destroyed every bridge, dam, mill, factory, and building it could reach down to the Hudson River. I well remember this river above the dam, and its lamb. like character in summer, for I built a railway on its banks, and have many times crossed it on stepping-stones without wetting my boots. The European news of the past two days tells us of floods in Hungary, and that many dams have been carried away on branches of the Danube. I for one would rather trust to a tunnel than a dam. I have had a good deal to do with dams, and I feel towards them as Robert Stephenson once told me he felt toward railways, that he was afraid of them.

There are other things that I would be afraid of in the construction of a canal with elevated reaches on the side of a valley where such rains occur as are frequent in the San-Juan region, I mean the melting and running of the embankments. Once on arriving at Panama on my way home I was told I could not cross the Isthmus, as there was a washout a few miles from Panama. I took a hand-car, went to see it, and found Col. Totten there making an embankment of sleepers. This same embankment had been washed out three times before, and every time it had been, when rebuilt, reinforced by a row of piles, close together, on the down-hill side. Col. Totten said to me, "You see this embankment could not go out down hill this time, so it has gone *up hill*." It had actually squashed out on the up-hill side, and had run very much as molasses would run; a horse or man going into it would soon have gone out of sight. To know the Isthmus and its rains, and what rains can do in the way of making running mud out of embankments, it is necessary to go there and see it, for no one can imagine it from any pen sketch. I have an impression that all the arguments that

can be urged against the Panama route will hold good against the Nicaragua, while the Panama route, adapted to have locks, has the advantage over the Nicaragua in the matter of length and harbors at the termini.

Mr. Menocal's estimate of cost appears to be made as many other estimates of cost of public works have been before his time, by dealing in too small figures, and making omissions. His estimate for drains (I suppose this covers aqueducts over side rivers, culverts over streams, changes of channels, waste-wiers, sluices, &c., &c.) is magnificently deficient, and I see no items for protection walls, inside and outside, puddle walls, lining to prevent leaks, gravel facings, &c., &c. Also draw bridges over the canal, light-houses, machine-shops, and whole villages of buildings for residences, &c., store-houses, &c., &c. I suppose these are all in the twenty-five per cent. for contingencies. I have found in practice that after estimating every item I could think of, the twenty-five per cent. for contingencies came in as a most comfortable assistant at the end. Captain Young, who built the Utica Railway, used to say that the only safe way to make an estimate, was to take the largest quantities you could get from the profiles, carry them out with the largest prices you ever heard of, add twenty per cent., and then double the whole. When the first estimate of the Hudson River Railway was made, there were many arguments offered to show that it could be built for about "half of nothing;" the engineer gave the size and number of every arch and culvert required on the whole 145 miles, for each division. I, having a love of statistics, counted them, and found there were about sixteen or eighteen in all. Now, this same engineer had just before built the Croton Aqueduct over forty miles of the same route, and close to it, and had forgotten that he had built over three hundred culverts, arches, and bridges, on that forty miles. The protection walls for this railway, amounting to over 400,000 cubic yards, were estimated to cost fifty cents per cubic yard, and it was forgotten that the protection walls of the Croton Aqueduct (now nearly all, inside of forty years, replaced by better walls) cost $1.75 per cubic yard. I mention these things to show how errors creep into engineers' estimates, even among the most conscientious their zeal, their desire, their anxiety to see their project go down the throats of somebody, overrides their judgment and stores away in oblivion for a time all their hard-earned experience, making true at this day the old Roman motto, "*Men try to believe what they wish to be true.*"

The Nicaragua route calls for the construction of artificial harbors at each *terminus*. This is a most unfortunate feature of this route. Such things have to be approached with fear and trembling, and a pocket full of money, and after they are built and handed over as something to be proud of, they, or their parts, very often go on excursions up and down the coast, through the alluring enticements of the wind and the sea. Some have their usefulness nipped in the bud by a failure to find funds for their completion, as was the case with the Dover Harbor, in England. I had occasion to examine those works in 1853, and then came to the conclusion that although "John Bull's" purse was long and large and full, that he had better leave that work alone, and since then he has left it severely alone. The one long wall which I saw in 1853, I was again on in June of this year, and found it had neither grown higher, longer, nor more complete, and its partner had never been attempted. In March of this year I walked, or rather clambered, out for a short distance on the concrete breakwater for the harbor of Port Said, at the northern *terminus* of the Suez Canal, found that it was far from finished, and unless finished would in a few years be knocked to pieces and rendered useless. In November of 1878 I had a chance to examine the concrete works of the harbor at Algiers, built by the French, evidently at great cost. The waters of the Mediterranean had quietly or unquietly, as the case may be, just knocked a considerable part of it into a "cocked hat," and the Algerines were, in their faith, no doubt, praying to "Allah" to knock the "cocked hat" into "pi."

Artificial harbors are contrivances to be avoided, if possible; they are apt to give engineers sleepless nights, to deplete plethoric pockets, and vanish when called on by the winds and the waves.

I have some experience in sleepless nights produced by things of this kind, for I built out into the Pacific Ocean the first pier ever built on the whole coast of South America, that a big ship could haul alongside of. The "Brave south-west winds" as Maury called them, were my friends for thirty days out of thirty-one, then "Æolus" sent "Boreas" down to make things lively with his "big guns," and at the same time make an engineer's heart sink into his boots. During construction I often saw the northers rolling in the waters, which went over my pier from 20 to 30 feet high, and bid fair at times to carry the whole structure, with its 80 000 tons of stone, on to the beach.

Mr. Menocal estimates the locks between gates to be 400 feet long;

a lock of this length will pass a vessel of only 360 feet. Thirty years ago vessels of 360 feet long were scarce articles; we have now lots of vessels of 450 feet, and vessels of over 500 feet are being built. Who can say what will be the length of vessels in another thirty years? The locks of the Erie Canal of 1825 could not pass boats of half the size that are now locked through.

The locks of the Delaware and Raritan Canal had not been in use thirty years before they had to be doubled in length. I came through the Suez Canal in March in a Peninsular and Oriental Royal Mail steamer from Hong Kong and Bombay, that was over 400 feet long; other steamers of that line are over 450 feet long. I saw a number of steamers in the canal, and judge that most, if not all of them, were over 400 feet long; it would be a sorry mistake to build a canal with locks that cost over $300,000 each, and find that they could not pass these giant craft, for they are the cream of the business a canal company would seek.

The Suez Canal is virtually a straight line. When I arrived at Lake Timsah we found a huge steamer stuck in the mud in the lake, and a crowd of Arabs unloading her; the canal ahead was blocked; I took a steam pilot-boat, went ahead to see the difficulty, and found that a passing steamer had run into and sunk one of their large dredging machines; this once clear, the next day our Leviathan attempted the passage to Port Said, but we had hardly run in the canal a mile before our vessel run her bows into the right bank, her stern slewed around and went into the left bank; there we stuck for two hours, and in two hours more our craft was laid along side for the night, that being her second day in the canal; this steamer entered the canal at 4 P. M., March 22d, and arrived at Port Said at 10 A. M. on the 24th, taking 42 hours to run just 100 miles in a sea-level canal, virtually one straight line. The very next mail steamer of the P. & O. line that came through after I did, ran into the bank, her stern swung into the opposite bank, and broke off two of the blades of her propeller. Accidents like this, of running into the banks, being apparently common on straight lines, it would be well to examine carefully into the manner of working these long steamers around the sharp curves of the proposed Nicaragua Canal.

We in America know that the English locomotives have a very unmannerly habit of jumping the track at sharp curves, which habit we in America have almost entirely eradicated from their vicious propensity by

rendering them subservient to the ameliorating influences of a "Bogie," a mechanical persuader which accomplishes the object in a most satisfactory manner; if this admirable invention could be applied to a ship, we might overcome the difficulty; as yet I see no manner of making the application, but the Yankee brain is prolific, and some genius may work out the conditions of this important problem. Old canal men and sailors accustomed to handling these huge vessels will look with a smile on the estimate of 38½ hours to pass through a canal 181½ miles long, with many sharp curves and 22 locks; also the estimate of 20 minutes to a lock; to fill or empty a lock in 12 or 14 minutes would not be a difficulty, but that is only a small part of the time required to pass a lock; it must be recollected that a vessel has to be "slowed down" long before she reaches a lock, and in most cases come to a dead stop before she enters the lock, then to be hauled in slowly and with care, for if a large steamer, weighing with cargo 8 000 or 9 000 tons, enters or approaches a lock with any amount of headway on her, she will probably walk through the lock without asking permission, and in much less than 20 minutes. If any such trade as would certainly be offered to a sea-level canal were offered to a canal with locks, there would, most undoubtedly, be great detention at the locks, by one vessel finding another vessel in the lock, other vessels ahead of her, gates shut, lock empty, &c., &c. If any one thinks these large vessels can be started and stopped, and turned like children's toys, let him go down to the piers in New York and see one of these large steamers arrive and get berthed. I arrived in July in the Britannic, and we were full one hour from the time we touched the dock until the ship was hauled into her berth. Taking my trip on the Suez Canal as a base for calculation, I would make the time of passing the Nicaragua Canal as follows: the speed was a mile in 25.2 minutes; 181.25 miles at 25.2 minutes per mile—76 hours; 22 locks at 1½ hours a lock, 33 hours; total, 109 hours; or, say 4½ days, and this may be put in opposition to one single day of ten hours in passing the clear, straight, unobstructed 30 miles of the San-Blas route.

Mr. Menocal estimates the cost of the Nicaragua Canal at 66 millions dollars. Men with experience and analytical brains have criticised this estimate and found it deficient. I agree with them, and further believe that the dimensions estimated are not such as a World's Canal calls for and should have, particularly in available width and depth, and more particularly when carelessly handled ships are to be encountered. In going

out of Marseilles harbor just one year ago in a straight channel of double the width of the canal proposed, our French captain had all his yards squared; he met an incoming brig, his vessel did not touch the brig by fifteen feet, but his main-yard struck the foremast of the brig and snapped in the middle, broke the fore-top mast of the brig, and down it came with all its spars close to the spot where I was standing with some ladies.

In pushing and preaching the merits of the Nicaragua route, there appears to be a fixed intention to ignore the San-Blas route entirely, and "pooh-pooh" it out of sight; they may knock it down, but it will come up again; they may throw cold water on it, but it will come out of the fire brighter than ever; they may build the Nicaragua Canal, but the San Blas will be built too, and then it will require no very wise man to tell which will be the one used. In the papers and estimates made out to compare the different routes, I see nothing said of comparative cost of repairs and maintenance; leaving the Panama route out as an absurdity, the lengths of the San Blas and the Nicaragua are as 1 to 6, but when it is considered that one is a sea-level canal, with good harbors and without locks, cut for a large part of its length through solid rock, the southern half in an open "savanna" country, the whole easily made safe from the ravages of floods and drains; while the other route is on and parallel to a tremendous drain, where floods occur that may and probably would sweep the whole works to destruction in a few hours; where earthquakes may and probably would twist the locks so that the gates could be neither shut or opened; where side streams, with their floods, must cross the canal to get into the main drain; where the time of transit compared to the San Blas is as 5 to 1; where there are no good harbors at either *terminus*, and where one *terminus* is a notoriously unhealthy place, I think any careful and critical mind would put the ratio of conservation of the two routes not as 1 to 6, but as 1 to 20 or 30, or more.

A five-inch rain falling in twelve hours is a thing not unknown in the Nicaragua lake region; as the water-shed of the San Juan River is 12 500 square miles, a five-inch rain is represented by over 4 000 millions of tons of water, a greater part of which has to find its way to the sea by the San Juan river, and not take a great length of time either; it was undoubtedly after one of these great rain-falls that the San Juan River, rising above its banks, overflowed, and cut the

Colorado River into the territory of Costa Rica. Those who are curious in the matter, might calculate the foot-pounds of energy or force developed by 4 000 millions of tons of water falling 107 feet, and its power for doing mischief.

Apparently the only objection to the San Blas route is its cost growing out of a long tunnel, and the inability to say what kind of material would be found in the tunnel. Let us examine this great bugbear, the tunnel, and compare it with other works.

The "Desaguadero" in Mexico, cut by the Spaniards, as a matter of precaution against floods, two hundred years ago, required about three times as many cubic yards of rock to be removed as would be required to cut a ship-tunnel 8 miles long, 180 feet high, and 80 feet wide. Now, if the Spaniards could do that two hundred years ago, should we, who have steam drills and wonderful explosive compounds, shrink in fright from a work of only one-third the size?

The St. Gothard Railway, now nearly completed in Switzerland, to connect the northern railway system of Europe with that of the South, is a work that involves immense difficulties. It has on its line forty-six tunnels, one of them at the summit being over nine and one-fourth miles long; one of them the engineer pointed out to me as being cut to secure the railway line from being buried by avalanches. Seven of these tunnels in complete circles of 1 000 metres diameter, are cut merely to get distance, and keep the gradient down to their fixed standard of 1 in 40 (132 feet per mile), and this tremendous work is being built for the very limited business of a railway. With this example staring us in the face, are we Americans, who boast ourselves of doing things with a bigger "auger" than our neighbors use, to turn tail and run away from a tunnel that would, if built, command the trade of the world, give us a grip on the trade of the whole Orient, allow us to manufacture all our own cotton and find a market for it in China, connect our Pacific possessions by a less expensive route than any railway can supply, consolidate our Union in stronger bonds, and lead in time to our becoming the most central and most powerful people in the world.

It has been objected to this tunnel, and reiterated by Mr. Menocal, that the rock found in it may be too soft, or of a character not fitted to support its sides and roof. This is all "moonshine." We know from mines and cuttings over all that country, and from surface rock that

crops out everywhere, just what we may expect; there is but one material existing that we may be afraid of, and even that was successfully overcome in the Box-tunnel of the Great Western Railway of England—I mean quicksand, and that we know we will not find under the rocks of the Isthmus. Mr. Menocal thinks we have not the data by which we can calculate the cost of the San-Blas Canal as fixed and clear as they have for the Nicaragua Canal. If they have not these data it is their fault; they should have got them; but I contend that we have all the data required, and more reliable than any data ever can be, on a line parallel to and close to a line of drainage, that Domine Sampson might call with truth, "prodigious;" we have the length of the whole route; we know what is tunnel and what open cutting; we know to a certainty that we can turn off all the streams and the one river, the Chepo or Bayano, and render them harmless to do evil. We know that we have good harbors on this route; we know that we have rock to contend with in fixed quantities, and, by estimating it as granite, we know that the estimated cost cannot be far wrong. It has been intimated that earthquakes might make a tunnel unsafe and dangerous; in answer, I would say that we have sixty-two tunnels on the line of the Oroya Railway in Peru, that many of them are completed and have been run through for years, and to this day I have never heard of any injury done to a tunnel on that line from earthquakes, which are much more frequent there than on the San-Blas route.

We need not be afraid of striking a great vein of gold or silver, for in a case of that kind, unless the tunnelers become demoralized, such a vein might be coaxed into paying all or a part of the expense of the tunnel. This is not a speculation, unprecedented in facts, for my old friend, Genl. O'Brien, when forced by San Martin, the Liberator, to accept the Salcedo mine, in Peru (the richest mine at that time that had ever been worked), for his services in the wars of independence in Buenos Ayres, Chile, and Peru, struck a rich vein of silver in cutting an adit level from Lake Titicaca that paid all the expenses of cutting the tunnel for a long time. If some of the Bonanza kings of California could be induced to suspect another Comstock Lode on the line of the San-Blas tunnel, they would cut the tunnel for the fun of the thing, and thank you for the chance. But if we throw out the silver speculation and return to the "hard-pan" of a hard-hearted contractor's prices we may have the following estimate to stare in the face:

14 millions of c. yds. of rock in the tunnel above the sea level (the tunnel being 8 miles long, 150 feet high above the sea, and 80 ft. wide), at, say, $3 per c. yd	$42 000 000
4 millions of c. yds. of work in tunnel below the level of the sea (this part being 80 ft. wide and 30 ft. deep), at, say, $8 per c. yd	32 000 000
22 miles of open (earth and rock cutting) canal at the same price Mr. Menocal estimates his line from Del Medio to Brito, where it is all rock, at, say, one million per mile	22 000 000
Diversion of the Rio Bayano, say six times as much as Mr. Menocal estimates for the diversion of the San Carlos, $283 578 × 6	1 700 000
2 400 acres of grubbing and clearing, at $100 an acre, the same as Mr. Menocal estimates an acre at, this gives a width of 875 ft. for 22 miles, say	240 000
Diversion of other streams, all small ones, say	1 000 000
Light-houses, piers, store-houses, buildings of all kinds, say	1 000 000
Total	$109 940 000
Say	110 000 000
Add for contingencies 25 per cent	27 500 000
Grand total	$137 500 000

The above estimate is considerably above the estimate of Mr. Menocal for the Nicaragua route, but I will here venture to predict that it is very much nearer the truth of what the Nicaragua Canal will cost, if ever built, than Mr. Menocal's estimate. We may as well stare the truth in the face now as at any other time; it is the most honest way.

The people of the United States have had too much to do at home to look with much enthusiasm on works in distant countries or study with care the vast interests wrapped up in foreign trade; but the day is fast coming when they will be forced to know and value this matter, and then they will cut a canal through the Isthmus on the shortest route that can be found, no matter if there is a Nicaragua Canal or not. I am

glad to find that all of the old canal engineers that have ever visited the Isthmus, and made a study of this problem, join me in the opinion that the San-Blas route is the best for a sea-level canal, and the proper one to construct. And Mr. Kelley, who has spent his life and a fortune in surveys and study of this matter, and who has as clear an understanding of the whole subject as any man living, also most enthusiastically gives his adherence and support to that route as the only one that can satisfy the coming demands of trade, which is doubling up on us much faster than any one but those who study statistics could imagine.

As I feel convinced that the indirect benefit to the nation to be reaped from this canal is far greater than any direct benefit to any company, I would propose that the canal be cut, not on the line that is found to be the cheapest in first cost, but on the line that can be worked the easiest and quickest, and in the most reliable manner as regards line, level, repairs, and freedom from accident, even if it costs double the amount of the cheap and unreliable line. And in view of this end, I would, if I were the Government, offer to any company that would undertake this great enterprise, to *give* them one-half of the entire cost, and let them enjoy the rights, immunities, and profits of the whole thing, free of interest, for one hundred years; but reserving to the Government the right to take the whole at the end of one hundred years by paying one-half the original cost. It may not be out of place in this discussion to bring to the notice of the people of this day the prophetic writings of some who have preceded our time. Gouverneur Morris, the statesman, in a long letter, written in January, 1801, to John Parish, in Europe, says:

"As yet, my friend, we only crawl along the outer shell of our country. The interior excels the part we inhabit in soil, in climate, in everything. The proudest empire in Europe is but a bauble compared with what America will be, must be, in the course of two centuries, perhaps in one."

Robert Stephenson, the engineer, in writing to his brother-in-law (in London), when he was here in 1853, after speaking in the most enthusiastic terms of the progress and development of this country, says:

"Considering these circumstances, and looking at the boundless rich territories which are being opened and extended daily, I confess I am entirely at a loss to figure to myself the part which the United States

are destined to play in the world's theatre; their influence must daily increase and when her inhabitants reach the coast of the Pacific their power, must become predominent as a commercial nation." * * "Coal, which has hitherto given England her commercial superiority, is possessed by the States in almost incredible quantities; it has as yet scarcely been touched, because other sources of profit have presented themselves; but the day must arrive when, like England, the Americans will become a powerful manufacturing nation. If this be anything like the truth, how strangely must the relations between the civilized nations of the earth be changed and then arises the question, so full of interest to an Englishman: Will England still maintain a good position in the struggle of countries, or will she, like other empires that have dropped into the past, begin to decline, and in her infirmity, like an aged parent, be obliged to look to her trans-Atlantic children for aid and support?"

We are fast arriving at the point predicted by Mr. Stephenson. We must have outlets for our products. In what direction can we turn for a market for our manufactured goods but to the shores washed by the Pacific and the islands of that great ocean? China and Japan, Australia and New Zealand, invite us to a close intimacy. The Spanish republics of the South American West coast offer us many tempting chances for trade enjoyed at present almost solely by England. The Orient and Occident of our own country wish to shake hands over a cheaper route of transport than any railway can supply. Let us mingle the waters of the Atlantic with those of the Pacific on the best, shortest, and most reliable route that Nature has furnished, or let us leave it entirely undone, for others of greater courage to accomplish.

I find in some of the discussions on this important problem that the San-Blas route is called impracticable, but in no case is an attempt made to demonstrate the impracticability. Surely it cannot be because it is so short, so straight, so free from floods, locks, dams, and aqueducts, or can it be that it is rejected on account of its having good harbors, and in a healthy region, free from swamps and lagoons. What can the claim of impracticability spring out of that blinds the Nicaragua promoters to the many points of merit of the San-Blas route unsurpassed and unsurpassable by any other route; there is but one point on this route that the objectors can fix their harpoons into, with any shadow of a chance of bringing it home to the minds of men as a dead fish. It is the tunnel; that is the bugbear, the stumbling block, that

narrow minds and unprofessional minds cannot climb over, creep under, or swallow whole. I am inclined to think that the tunnel is one of the best features of the whole route; it will cost, no doubt, a rousing big sum, but the amount will be a mere bagatelle to its value and importance, and when built it will be the surest and safest portion of the whole route; it will be through solid rock, and remain forever intact, requiring little or no repairs. The heading, a very insignificant part of the whole, would cost as much per cubic yard as any railway tunnel, but the balance down to the seawater level could, in that region, be done cheaper and quicker than an open cut of the same dimensions, where the average haul was the same, for the reasons that the men can work continuously without being driven off by the great rains that are so common on the Isthmus, and they can work, as in all tunnels, night and day. This tunnel can be cut cheaper per cubic yard than any railway tunnel could be in the same region, and for the reasons that the great width of the tunnel allows the men abundance of room to work in, and use all classes of labor-saving machinery; the force of the explosive compounds can be utilized to a greater extent, as there is more room for expansion. Any contractor can afford, and will afford, to take such an immense work at much less per cubic yard than he would think of asking for a small tunnel, such as are built for railways, for he can afford to procure and use the most perfect, extensive and efficient machinery ever used on any tunnel ever cut. I was shown at the St. Gothard Tunnel steam drills that by slow motion and high pressures would walk into granite as a knife would into cheese; there was nothing used on the Mount Cenis Tunnel to approach them in efficiency. I was shown air compressors that kept their great reservoirs night and day under pressures of 110 pounds to the square inch, and without difficulty; it was with difficulty and uncertainty that the air compressors of the Mount Cenis Tunnel could keep the pressure up to 60 pounds to the square inch. We are clearly a progressive race, and it would be a wise brain that could predict with certainty what advance may be made by some live Yankee in tunneling machinery when we come to cut a ship tunnel. I have copies of the entire maps and profiles of the St. Gothard Railway, and I have no hesitation in saying that they show the most complete and perfect surveys yet made for any public work ever attempted by man. There were 400 engineers and their assistants employed on these surveys, many of them highly educated and experienced men; their estimate of the cost

of this great work, 109 miles long, was 187 000 000 of francs; that was the sum placed before the public at the time the International treaty (of Germany, Italy and Switzerland) was signed, and a company formed to build the works, but they were only started when it was discovered, that, as usual, the works had been underestimated, and the cost was going to be swelled to 289 000 000 of francs, showing an error in the first estimate of 102 000 000 of francs. Where was this tremendous error made—in the great tunnel? No, for the estimate of that was 70 000 000 of francs. Monsieur Favre took the contract to build it at 50 000 000 francs, and if he had lived would have completed it in the coming year, without asking favors or assistance. There is an inference to be drawn from this statement of amounts, regarding estimates and costs of work in tunnels, and general work, which the intelligent reader will quickly see. Mr. Menocal estimates his great canal, 181¼ miles long, at $66 000 000; the St. Gothard Railway is to cost, for 109 miles, about $58 000 000; now, if the canal costs only as much per mile as this railway, it will cost about $97 000 000. The railway costs about $532 000 a mile, while Mr. Menocal estimates this great canal, with artificial harbors, great locks, but not large enough for great ships, great excavations of rock under water, great aqueducts and great dams, all liable to be swept out by the first great flood, and great embankments (sustaining a hydraulic head of 26 to 30 ft.) perched upon side hills, all of which may be washed out through the never-ending labors of rats and roots in boring holes, all, complete and ready to accommodate the trade of the world, at $346 000 a mile.

It may be claimed that the rock excavation under sea-water level is the impracticable point. If so, are not the excavations under water on the Nicaragua route equally or more impracticable. Let us stare some of the facts of this matter in the face. Nearly all of the excavation of rock under sea level on the San Blas route will be in still water, not affected by currents or winds or tide, while the same class of excavations on the Nicaragua route, in the beds of the San Juan and Rio del Medio, and in the bed of the lake, will be severely affected by currents in the river and waves and winds in the lake. To excavate rock in a swift current, such as is to be seen in the San Juan, is a species of fun engineers do not much covet. General Newton preferred to burrow under rather than attack the current at Hell Gate. Then, as to the work to be done out in the lake, I have an impression that this feature

has been very much under-estimated. Suppose we subject this to a few figures, from known data, at one point. It is to be regretted that there is no good hydrographic survey of this lake, so we must be content with such data as we can pick up. The history of this lake and river show that, some years ago, a certain Capt. Sheppard took his schooner from the Gulf up into the lake during a flood. He did this with great labor, by taking off his false keel and taking out his cargo, reducing the draft to about three feet. Once in the lake, he put on the keel, and, with the vessel loaded—drawing seven feet—he could not, in the dry season, get within two miles of San Carlos, at the upper end of the San Juan River. Now, taking this little piece of history to calculate by, and knowing the material to be rock, I make it that a canal only 100 feet wide (I call it 100 feet wide, not because that is enough, by three or four times, for the passage of a ship subject to the buffetings of winds and waves in a great lake and the canal out of sight, but because 100 feet is sufficient for the demonstration I wish to make), cut from the mouth of the river out into the lake, so as to have 28 feet of water all the way to deep water, will call for the excavation of about 1 100 000 cubic yards, which, at $8 a yard, will come to $8 800 000; but, for the sake of being generous and accommodating, suppose we call it the half of the above sum, and then it is six times as much as Mr. Menocal estimates as the cost of all the work to be done in the lake division, including mud and gravel, which, it is admitted, has to be dredged, and also the rock under water at the western end. Heaven only knows how much is required to be cut for a channel to get into the mouth of the Rio del Medio.

Let us return for a moment to the San Blas route, and take a fair, square look at the rock to be excavated there below the sea level. In the tunnel, where the great mass will be found, it may be dry, and it may not. Take it on the side of the "may not," and allow it to be as wet as ever was seen, is it supposable that any engineer in his senses, with but a smattering knowledge of hydrostatics, would attack it under water, when he can so easily build bulkheads, pump out the water, and work out the rock just as he did above the level of the sea. With this system of working kept fairly in view, I have a fancy that any intelligent man can see that this rock in the tunnel will come out more quickly and cheaply than will the rock in the bed of the lake, when the winds and the waves will be playing "hob" with the drilling machinery, and at times driving the men from their work. But suppose the work finished—who can esti-

mate the distress of mind of a captain when he finds his ship in a great lake with a wave-swell of 8 to 10 feet and only 2 feet of water under his keel; and that, too, only in a canal out of sight.

In my estimate of cost I dealt in big figures, and estimated for a depth of 30 feet of water. To bring this to the 26 feet of Mr. Menocal's section, there should be deducted over $4 000 000. Then again the tunnel, on more accurate surveys being made, may be reduced to six miles instead of eight. This would reduce my estimate again by $15 000 000, and then the 25 per cent. for contingencies would come down some $5 000 000, making in all some $24 000 000 of reductions. But I prefer to let it stand as I had it, at $137 500 000, and time will show who comes nearest to the truth, for it is in my eyes a sure thing that a great world's canal will some day be cut on the San Blas route.

As the transit of any of these canals will have to be suspended during the night, and as the San Blas route is so short that it can be navigated from end to end in ten hours, or less, and as one passing place (at south end of tunnel) only is required, the whole of the rest of the canal can be made, and should be made, much narrower than would be allowable and required on the Nicaragua route, where passing places must be frequent and provided between all the locks.

As sailing vessels are destined to form a great feature in the traffic of this Isthmus Canal—a feature that the Suez Canal is entirely deprived of—I beg to refute the claim made by the Nicaragua projectors, that the Bay of Panama is difficult to get in or out of on account of calms. I have been at Panama for weeks—I have been a guest on board of a United States war vessel for two weeks in that bay—and I never saw a day when a vessel was detained there, or prevented from coming in by either calms or storms.

New Yorkers would feel very indignant if told that their port should be shunned on account of its being difficult to get in or out of, and yet, I suppose, they all know that sailing vessels have often been for days outside, afraid to come in, and for days, in the lower bay, afraid to go out, during times of storm and fog—two hygrometric and meteorological features never met with in Panama Bay. Let us place the "calm" claim alongside of the "impracticable" claim, and send them both to the safe keeping of croakers. Intelligent men of this age are not going to take much stock in those two articles of Nicaraguan faith.

In getting from our shores to China and Japan, the great objective

points, we as a growing commercial nation should look with much respect and admiration on the pacific character of the Pacific Ocean. The Spaniards of old used to say that all a "skipper" had to do on leaving Panama for the Phillippine Islands was to set his course, tie his rudder fast, go to sleep, and not wake up until he reached the end of his voyage. Ships going from Panama to China can take a trade wind going and a trade wind returning. When the canal is cut, and we have a new highway to the East, this feature will play an important part in assisting us to the largest share of the trade and traffic of the Orientals—a trade which for centuries heaped wealth into the coffers of the Greeks, the Jews, and the Armenians of the Mediterranean—a trade that England seized and grew her wealth and power out of, when Vasco de Gama showed her a new way to the East by the Cape of Good Hope, four hundred years ago—a trade that is destined to fall into our hands and give us wealth and power such as no nation ever held, as soon as we can muster courage enough to cut an Isthmus Canal on the shortest route that can be found, and throw it open for all the world to enjoy as best they may.

It may not be inopportune to mention in connection with this discussion that a late commanding officer of the United States Navy, now living in Washington—a gentleman well acquainted with Nicaragua, Panama, and the Pacific Ocean—once said to me: "I should be very loath to allow any ship I commanded to be run in a canal and locked up a hundred feet above the ocean. I should be afraid of never getting down again."

In connection with the risks run by placing a big body of water on the side-hill slopes of a river valley (in a region of great rains) in a prism made of cuts and embankments, crossing spurs of hills and ravines, and also to show the fallibilty of man's estimates, I beg to mention a little incident that occurred on the line of the Oroya Railway, in Peru, in the Valley of the Rimac. The final location had been made, and for some time the construction of this railway had been going on in a region almost rainless. At a point in the valley where the line crossed the mouth of a ravine we had left an opening to be filled by a bridge of 100 feet span. At the head of this ravine some poor *peons* had been cultivating the soil on the top and side of the mountain by bringing the water of melted snow from other and higher mountains for irrigating the land, as water in many parts of Peru is valued like gold. The peons, with great

labor, puddled and protected the edges of their "chacras" so as to prevent loss by waste. The water sunk into the soil, and permeated down deep through stratas of alluvium, gravel, clay, and loose rocks. This was close to and on the side hills leading down to the Valley of the Rimac. This gradual permeation of rock and gravel, clay and sand, with water had, no doubt, been going on for a long time. The water was trying to find its lowest level. The rocks and the earth were only waiting to be released from the bonds of cohesion that had held them on the mountain side for ages to show what attraction of gravitation could do. Day by day this insinuating element, water, was doing its work, in the dark and in the night. Ceaseless, unopposed, all powerful, it was cutting and severing the bonds of cohesion. The people in the valley in front of the ravine rested in quiet content. The peons of the mountain imagined no evil genius underlying their crops, but in a moment when no one suspected danger the whole mountain side started for a race to the valley. Five millions of cubic metres (about ten millions of tons) of rock and earth, gravel, mud, and water came rushing into the valley, crossed its whole width of 1 400 feet, surged up against the opposite side, rolled over and crushed out of sight all the houses in its annihilating course, and filled the valley with a dam 1 600 feet wide on the bottom and 108 feet deep. The average vertical fall of this vast body of earth was about 1 500 feet, and the horizontal movement over 5 000 feet. Surely water has power, and we are entitled to place it with its sister element, fire, as good servants but dreadful masters. Gouverneur Morris, the projector of the Erie Canal, proposed that it should be built without locks, and on a line that would give it a uniform descent per mile from Lake Erie to the Hudson River. What a magnificent idea. It was too magnificent for the time. A line of this kind would carry the canal to the south of Cayuga and Seneca Lakes. With fifteen millions of tons of surplus grain in the far West seeking a market on the Atlantic seaboard, it would soon make New York the imperial city of the world, if it could find its way by water lines, without one check or hindrance, from the great grain fields to the great city.

A canal built as Morris proposed would not have a greater descent per mile than is now existing in the Ganges Canal in India, which has a fall of fifteen metres to the mile, and is navigated in either direction with facility and certainty. I mention this canal and its gradient to show that even a guard-lock is not a necessity at the south end of the San-

Blas route to provide for the current that would be created in the canal at extremes of high and low tide of the Pacific, but a guard-lock there would be a convenience and an economy.

Discussion by Frederick M. Kelley.

It is very gratifying to notice the lively interest being taken by the civil engineers of our country in this question, as they by profession, education and experience are the only class competent to make surveys, locate the canal, estimate the cost, and manage it when constructed; hence, they ought to take a prominent and leading part in the discussion.

With all due respect to the intelligence and ability of naval officers to build and sail ships on the ocean, their want of experience and knowledge in constructing railroads, canals, bridges and other great works on land, makes them comparatively incompetent to decide so great a question as a inter-oceanic canal. It is true that some, if not all, the late Government expeditions employed more or less civil engineers to run the lines, but the chiefs in command were naval officers, whose orders they were bound to obey.

The navy part of the Lieutenant Strain Expedition in 1852, and Captain Craven's in 1858, were failures, and of Commander Selfridge's surveys I have always regretted that he, so well supplied with government instruments and men, did not go over the entire route, instead of making only a partial and hasty examination, and thus throwing doubts and uncertainty on much the shortest of all the sea-level routes with its good harbors and longest slope of open cutting on the Pacific, the dryest side of the Isthmus.

The facts are, the San Blas route has good natural harbors at both ends, requiring no improvements or breakwaters whatever—is the shortest, best and cheapest sea-level route known—is about 30 miles long, and with the exception of the Atrato-Napipi has less material to remove than any other route, and the canal when built will cost very much less to keep in repair, and will afford the greatest, quickest and cheapest facilities for all kinds of ocean steam and sailing vessels to pass the Isthmus for centuries to come.

That is what the commerce of the world demands, and will finally have, cost what it may.

Mr. Menocal says the San Blas Canal will cost twice more than the

Nicaragua Canal, and he might have added it will be worth three times more in consequence of the less cost of maintenance and the greater facilities it will afford for the passage of large ships.

The Nicaragua Canal advocates say that locks are used all over the world. So, it may be said, they are condemned all over the world.

Every engineer avoids them, if possible, knowing they are tedious, expensive things to keep in repair even in our mild, dry climate; but in the excessively wet and flood-water, iron-and-wood-decaying climate of the Isthmus, they would indeed be very expensive structures to keep in order for the passage of large ocean vessels.

Locks to canals are what high grades are to railroads, most expensive and difficult obstacles to overcome. Chiefly on account of high grades, the expense of running the Erie Railroad is about 70 per cent. of its receipts, while on the New York Central R. R., where the grades are easy, the running expense is but about 50 per cent. of the earnings, and the difference of 20 per cent. in favor of the latter road pays large dividends to its stockholders, while the Erie has paid nothing to the stockholders for many years, and there is no telling when, if ever, it will earn a dividend.

I have no faith whatever in the durability of earth embankments along a ship canal on the Isthmus. The heavy rains in that country will wash them into the canal, hence I have always maintained that the more miles of rock the canal passes through the less walling will be required to keep the banks from caving in—the more solid and durable will be the structure, and the less it will cost to keep in repair.

If the canal is excavated through 60 miles of earth, 120 miles of something besides dirt will have to be substituted to keep the banks from falling in during the heavy rains.

Even on our New York State canals the embankments are watched with jealous care, and notwithstanding the use of steamboats to lessen the expenses and increase the speed of transportation has been urged again and again, still the authorities hesitate for fear they will wash the banks.

It strikes me that every sensible man must see at a glance that a canal even 200 feet wide, located in the tropics, where the rains fall in torrents, the like of which is unknown in this country, and having great ships with their tugs passing through and washing it daily, must have something more solid and substantial than earth to keep the banks from caving in and filling up the canal.

Even the natural banks on the Atrato River, the formation of centuries, and on which grow all sorts of tropical trees and vegetation, giving something like stability to their character, are honeycombed with holes and crevices its entire length, and through these the water rushes whenever the river rises and falls during the rainy and dry seasons, carrying down endless quantities of silt to be deposited on the bars at the mouth, like the Mississippi.

This is one of the important reasons why I advocate the San Blas route.

Of the 29 389 828 cubic yards to excavate or remove on that line 25 543 939 cubic yards is rock and the remaining 3 955 889 yards is earth.

On this point and the tunnel question, when discussing the San Blas plans at the Paris Canal Congress, in May last, Mr. Favre, the St. Gothard Tunnel engineer and contractor, said: "I take the same views as Mr. Ruelle, and like him I prefer tunnels to ditches and river navigation. The construction of a tunnel would give place only to expenditures well known, and which could be determined in advance. One could work in a tunnel without interruption, and the rains would cause no embarrassment nor delay. The security of the work would be complete, and there would be no fear of caving in.

"In consequence of all these considerations I do not hesitate to give "my preference to the canal terminating in San Blas Bay in spite of the "tunnel of 10 miles which that project would require."

It will be borne in mind Mr. Favre *supposed* that Commander Selfredge's *opinion* of the tunnel being 10 miles long was correct.

Sir John Stokes, on the same occasion, said: "As for me, I give my "preferences to the San Blas project," and on another occasion, returning to the subject, he said: "The project in question (San Blas) would "avoid several obstacles and solve advantageously several difficul-"ties. * * * *

"Besides, nothing would be more easy than to give the canal a mouth "independent of the Bayano, and thus avoid the very inconveniences of "which they had been speaking."

Mr. Conrad, the Holland engineer, also advocated the route.

The opponents of the San Blas route estimate the tunnel at from 100 feet to 125 feet wide, and from 140 feet to 150 feet in height, above canal bottom, and thus succeed in swelling the cost of the work to almost fabulous sums.

This is very unfair, in view of the fact that at least 95 per cent. of all the vessels engaged in the Pacific trade measure less, and not more, than 40 feet in width of beam ; hence a tunnel constructed 80 feet wide at the water line, and 125 feet high above the bottom of the canal, will afford ample room for ships by striking their topmasts and hauling yards around to pass, and outside of the tunnel, where the canal is estimated 125 wide and 28 feet deep, there is abundant room for two large ships to pass each other.

Besides, the route is so short, there is no necessity for building the canal wide enough for two ships to pass each other, as going at the rate of three miles per hour 100 ships can be towed one way in ten hours, the same number back in the same time, and thus 200 vessels would be able to pass the Isthmus at this point in 24 hours.

No long-lock route could afford those accommodations in so short a time.

If a canal should unfortunately be constructed *via* the long 181 miles Nicaragua route, with its bad harbors requiring constant dredging and improvements to keep open, and encumbered with 18 or 20 locks, and as many more duplicate locks, making in all 36 or 40 locks, which will demand "eternal vigilance" and constant expense as the price of safety, it will prove so expensive, dangerous, and tedious that the ever-expanding wants of commerce will demand and execute a deep, wide, and short *sea level-canal*, through which ships can pass cheaply and quickly, on an even keel ; then there will be two canals, and it needs no prophet to predict which will become worthless, and remain as a stupendous monument of engineering and financial folly.

The heading in the San Blas tunnels amounting to 332 640 cubic yards, is estimated at $20 per yard.

The breakdown, amounting to 10 090 080 cubic yards, is estimated at $5 per yard.

Open rock cutting, amounting to 15 011 219 cubic yards, is estimated at from $1 75 to $2 50 per cubic yard.

Earth excavating, amounting to 3 955 889 cubic yards, is estimated at from 50 cents to $1 per cubic yard.

The masonry, of which there is 54 446 cubic yards, is estimated at $15 per cubic yard.

Concrete at $7 per cubic yard and pumping at about $2 000 000.

The whole work complete from sea to sea at $104 017 780.

If the tunnel should require lining its entire length, which the firm character of the rock does not indicate, then about $32 000 000 will have to be added to the above sum.

It is true the tunnel is one of large magnitude, and for that reason will afford much more light, room, and air for blasting operations than an ordinary railroad tunnel, and driven at both ends with steam and compressed air-drills, and other improved mechanical appliances, which will be brought into successful use as the work progresses, it can be constructed and maintained with less engineering skill than damming and locking, opening, and keeping open, the harbors of the Nicaragua route.

In view of the wonderful engineering achievments all over this country and Europe, and the success of the Hoosac, Mont Cenis and St. Gothard tunnels, and still greater ones being seriously planned and proposed under the Simplon Pass, in the Alps, and under the Straits of Dover, 20 miles long, between England and France, I can see no reason why engineers should recoil before the San Blas tunnel, which is not so long by several miles as the three last alluded to.

When the work is done we will have a deep, wide, sea-level canal through the narrowest part of the Isthmus, with good, natural harbors, easily approached on a wide open sea, permanent and durable as granite itself, fully satisfying the wants of the commerce of all nations, and which will remain a lasting monument to engineering skill and perseverance.

Discussion by Charles A. Sweet.

San Blas Route.

The route for the San Blas line was surveyed from Chepillo Island, in the Bay of Panama, to within about two miles of the Gulf of San Blas, where, by the hostile force of the Indians, and the desertion of our own men, we were compelled to return to the Pacific slope. The northern or Atlantic terminus of the proposed tunnel was located two days before, and all other salient points of the proposed canal, except at the Atlantic coast, were similarly obtained.

The limits of this paper will not permit as full a description of this route as may be desired. I will, therefore, give only the principal points of interest, trusting that the Society will allow me, in the near future, a

more extended article on this subject, thus completing the *official* data of all the favorable routes.

The total length of canal, from the Island of Chepillo, in the Bay of Panama, to 28 feet depth of water in the Gulf of San Blas is 30 $\frac{8}{100}$ miles, for ten miles of which the Bayano river is to be utilized.

The length of tunnel was fixed at seven miles, to have the following dimensions: 70 feet bottom width, a batter of 1 in 12 to 54 feet above, whence springs the arch, giving a total height of 118 feet, and a total area of 845 square yards. The tunnel is intended to pass but one vessel at a time, which can be easily done in two hours.

The section of the open work, in rock, is to be 100 feet width of bottom, a batter of $\frac{1}{4}$ to 1 to 32 feet above; thence an offset or bench of 10 feet in width, with the same batter through the rock; thence a slope of 2 to 1 through the earth to the surface. On the Bayano river a channel of 200 feet in width was estimated for. Depth of water throughout, 28 feet.

The Gulf of San Blas furnishes a magnificent harbor on the Atlantic side, and the Bay of Panama is unsurpassed on the Pacific. The extreme rise and fall of the tide in the Bayano river, at the divergence of canal, is 12 $\frac{86}{100}$ feet. The tides on the Atlantic side are from 1½ to 2 feet from ebb to flow. The mean half tides of the two oceans are on a level. The plan of construction was a tidal lock at the Bayano river, and a dam across said river by which the water surface in the canal could be maintained at ordinary high tide, and to terminate at the Gulf of San Blas with a lock of nine feet fall. The locks to be 450 feet between mitre sills, and 60 feet width of chamber. Total estimated cost, including 25 per cent. for engineering and contingencies, $104 017 780; annual repairs or maintenance, $100 000.

Time in transit, from ocean to ocean, for sailing vessels.

13 miles of open canal (no locks), at 4 miles per hour	3¼	hours.
7 " " tunnel, at 3 miles per hour (say)	2¼	"
10 " " river (av.), 4 " "	2½	"
2 locks, 30 minutes each	1	"
Total	9	"

PANAMA ROUTE.

From all the surveys, and my knowledge of the country, I am forced to conclude that a canal between Aspinwall and Panama, either with or

without locks, is impracticable, as I cannot see how it is possible to prevent the flood waters of the Chagres, which drains a large area of an annual rain fall of 137 inches, from overflowing and destroying the usefulness of the canal. The line crosses that river several times, and to construct a new channel for its waters would cost more than the whole canal, with much doubt of its permanency. I will add here that no such objection exists on the San Blas line.

There is only an open roadstead at Aspinwall, and the periodical "*Northers*" create sad havoc with the shipping, and destroy the strongest wharves that have been built there.

Mr. Menocal was the Chief Engineer of the Government Survey of this route for a *lock* canal, and the estimated cost of $94 511 360 was based on the following prices :

Excavation in rock	$1 25 to $1 50 per cubic yard.
" " earth	35 " " "
Embankment	15 " " "
Concrete	8 00 " " "
Excavation in tunnels, for feeder	4 00 " " "

Which, evidently, is about one-half what it would cost.

Nicaragua Route.

From Mr. Menocal's paper it seems that the size of locks, and depth of canal, are intended for about the largest ships in the Pacific trade, while the width of channel would not permit, even on a tangent, two vessels to pass each other having over 36 feet beam. Possibly, it is intended to have turnouts for the larger class of vessels, but no mention is made of it, and yet he assumes, in the computations, vessels 400 feet long and drawing 24 feet of watsr. The middle ordinate of 400 feet on a curve of 2 200 feet radius is nine feet. This, of course, must be deducted—once, from the bottom width, leaving 63 feet available, or two vessels of equal beam cannot be over 31½ feet The width of six feet on the two slopes are left for an easy passage. On a curve of 2 500 feet radius the ships could have but 32 feet beam; 3 000 feet radius, 32⅝ feet; 3 500 feet, 33 feet; 4 000 feet, 33¼ feet, and 5 000 feet radius, 34 feet. To increase the width of canal 50 per cent. there should be added ½ to the quantities, and the necessary width on river and lake should be 150 feet on the former, and 200 feet on the latter, which would increase the quantities, say, one-half, making a total increase to his aggregate estimate of $16 633 924, or a total cost of $82 356 071.

If the prices assumed are no greater than was used on the Panama line, a still larger amount should be added. Taking all these contingencies the total cost of construction would be as large as that estimated on the San Blas. The annual repairs or maintenance of canal would be in proportion to the length of line and number of structures. On this basis should tolls be charged. Estimated annual repairs, $1 000 000.

The estimated time in passing a vessel, from ocean to ocean, not counting detentions by accidents to the numerous structures, which must be expected, should be controlled by the lengths of levels, or distances between locks. No vessel can get a headway of four miles an hour between some of the locks as located on this line. Practically, the time would be for a steamer, in this particular line, with its numerous short curves and levels, as follows :

62 miles of canal, at 2 miles per hour		31 hours.
63 " " river, " 4 " "	(say)	16 "
56½ " " lake, " 8 " "		7 "
21 locks, 20 minutes each		7 "
Total		61 "

For sailing vessels with tugs it would take 81½ hours, or say 3½ days.

Discussion by JOHN C. CAMPBELL.

In the paper presented by Mr. Menocal on Inter-Oceanic Canal Projects, he assumes that the Isthmus has been sufficiently explored to enable us to determine the difficulties that would have to be met in the construction of a ship canal at the several places pointed out as presenting favorable indications for execution; then, giving certain data, concludes, that while a canal with locks seems to be practicable *via* both Panama and Nicaragua, the latter route possesses greater facilities for the execution of the work at a reduced estimate of cost, based on sufficient information to eliminate unknown elements.

The first question to be decided is, has there been sufficient explorations and instrumental surveys made to enable capitalists to invest their money in the building of a ship canal between the two oceans upon either of the proposed routes. I do not think that such knowledge exists or has ever been obtained.

Across the Isthmus of Tehuantepec a survey for a ship canal and railroad was prepared for, and Major Barnard of the United States En-

gineers was placed in charge. The survey was commenced and vigorously prosecuted, but in the tropical regions, where the forests are dense, much of the country uninhabited, with no other than mule paths for roads, anything like an accurate survey must be, from the nature of the case slow, requiring much time to obtain the knowledge sought for. This survey was begun in December, 1850, and in June of the following year (1851) the engineers were ordered out of the country by the Mexican Government. Some further examinations have since been made, but no instrumental surveys, across the Isthmus at this point.

In 1850 the Nicaragua Transit was established across Nicaragua, between Greytown on the Caribbean Sea and San Juan del Sur on the Pacific Ocean. Small steamboats were placed on the San Juan River and on Lake Nicaragua, and portages established around the rapids in the river, and between the lake and the Pacific a wagon road constructed, over which a part of the time during which this route was used, passengers and baggage in wagons were transported. The boats were in 1855 seized by the filibusters, and the route abandoned by the Transit Company. In 1851 Col. Childs made a survey for a canal on this route, but no work was done in construction. Now we have another survey by the United States Government, under the direction of Commander Lull, made by Mr. Menocal.

At Panama a charter was obtained by Mr. John L. Stevens for a railroad, a company organized, and Major Hughes selected to make the survey, to enable the company to decide upon the most practicable route. A party was sent down to San Blas, where an interview was had with the Indians who occupy the Isthmus between Porto Bello and the mouth of the Atrato River, but failed to obtain permission to make the survey. Major Hughes made a survey of the Chagres River and of the mule path between Gorgona and the City of Panama. In 1850 the work of constructing the railroad was, under charge of Col. Totten, commenced, and in 1855 was opened for traffic between the two oceans. This route, having been occupied for thirty years, the topography of the country and its facilities for the construction of a canal, either with or without locks, are well known.

From the line of this railroad to the mouth of the Atrato River no instrumental survey extending across from ocean to ocean has ever been made. Lieutenant Strain of the United States Navy, accompanied by commissioners of the New Granadian Government, attempted, in 1854,

to make a survey from Caledonia Bay to the Gulf of San Miguel on the Pacific Ocean. They procured Indian guides, but the guides, after leading them into the wilderness, deserted, and the party was lost in the jungles. Several of the party, including one of the commissioners, died from fatigue and starvation in this attempt. Gisborne, Cullen and de Puydt, at different times made reconnaisances, but no instrumental surveys were made.

Between the Bay of San Blas and the Bay of Panama an instrumental survey was made in 1864 for Mr. Kelley of New York, from the Bay of Panama to within three miles of the Bay of San Blas, but the party was there met by the Indians and driven back. Commodore Selfridge's party, in 1871, made an exploration from San Blas to a point where they found stakes planted by Kelley's surveyors. Evidence was obtained by Mr. Kelley's engineers to approximate the length of tunnel on this route, but Commodore Selfridge's exploration of one end of the tunnel line led him to decide that the length would be three miles more than was deemed necessary by those who surveyed for Mr. Kelley across the dividing ridge.

Here, for a distance of over one hundred miles, is the narrowest part of the Isthmus of Darien, across which no careful survey has ever been made, and until such survey is made it is really unknown where the best place is for a tide-level canal to be made.

Mr. Menocal furnishes the data on the Nicaragua route, as taken from his own survey; and the quantities we cannot question, though we may his prices and conclusions.

He says of the Panama route, the mean annual rain-fall is 124 inches, while that of the Nicaragua route he places, he says, approximately, at 52 inches on the Pacific Slope and 85 inches on the Atlantic side.

This statement is incorrect. The rain-fall on the Pacific Slope, it is well known, is much less than on the Atlantic, and he so states it on the Nicaragua route. The rain-fall given is as measured at Aspinwall, and the comparison should be given with that falling at Greytown, similarly situated on the Caribbean Sea, but instead he compares the rain-fall at Aspinwall with that at Granada, some 150 miles distant inland, giving it, he says, approximately. In relation to this matter Col. Totten says: "The large mean annual rain-fall is a serious obstruction to work, but not more so than along the San Juan, where, according to the reports I have heard from there during a residence of twenty years at Aspinwall, more rain falls than on the Chagres." One has only to look upon

a map of the Isthmus and examine the positions of Chagres and Greytown to see that this must be so.

Mr. Menocal says: "It is to the discussion of the most prominent features of the Panama and Nicaragua routes and their relative advantages and disadvantages to which I will confine myself."

The first question in such a discussion is, however, what kind of a canal shall be adopted, one with locks or one without. If the latter, then the Nicaragua route can no longer enter into the comparison.

The general opinion of the members of the Paris Congress gave the preference to the Panama route over the Nicaragua route either with or without locks.

We can only compare the two with locks. As a lock canal the Panama route offers the advantage of distance, using Mr. Menocal's figures, in the proportion of 42 to 181—an equal or lower height of summit level, less cost of construction, and better harbors.

Mr. Menocal says that the cost of a canal on the Panama route will be much greater than on that of Nicaragua.

In his paper we find no estimate of the quantities of excavation for a lock canal by the Panama route, he giving them for a tide-level canal, but not for a lock canal; but he gives the quantities calculated on the cross section recommended by the Paris Congress, as on the Nicaragua route at 70 781 555 cubic yards of excavation, and on the Panama route, on the Paris Congress cross-section, for a tide-level canal, as calculated by him, 73 925 230 cubic yards, or 4½ per cent in excess of the Nicaragua lock canal, he here keeping the same cross-section. To the Panama route is to be added the cost of the channel for diverting the Chagres river and its tributaries from the canal, which he says the committee of engineers at the Paris Congress estimated would cost $8 400 000.

Taking Mr. Menocal's figures, we have a tide-water canal at Panama with 4½ per cent. excess of excavation, and $8 400 000 for diverting the Chagres river from the canal, with the advantage of 42 miles of canal as against 181, as against the cost of locks on the Nicaragua route between points where there are no harbors at either end of the proposed canal.

Canal on the Panama Route with Locks.

Mr. Menocal locates the crossing of the Chagres river, by the lock canal at Matachin, at which point he fixes the summit level as necessary to give clearance to freshets in the river at 123.75 feet above tide. This

elevation of the summit is unnecessary. A good crossing can be had below Gorgona and another near Barbacoa.

At Barbacoa the railroad crosses the river at an elevation of 62.50 feet above tide, and with a length of 625 feet, and has passed all the water of that river safely for the last twenty-five years, except the last November freshet, when the water rose to thirteen inches below the track on the bridge. Taking his figures, the summit level would be here 108.50, but this height would not be necessary. He makes no allowance for the water-way of the arches, and estimates for an aqueduct 1 900 feet in length. From his statements in regard to the feeder, I think no very careful survey could have been made when he found it necessary to locate 7 tunnels and two siphons on the bank of the river in 10¼ miles.

To make these statements is sufficient to show that an engineer in two months time cannot carefully locate a ship canal of forty-two miles in length and a feeder of 10¼ miles without drawing very largely upon the imagination. He estimates the cost of 16 culverts and the necessary side drains, at $18 331 343, while on the Nicaragua route for 45 miles of canal along the San Juan river he estimates the cost of the drains at $340 000, though this 45 miles is all in the San Juan valley, a distance greater than the whole length of the canal on the Panama route.

Mr. Menocal in his paper further says of the Panama route, there is a total lack of building materials of all kinds fit for the construction of the works recommended. This is a discovery that no other man has made. The Panama Railroad has a number of bridges, all with stone piers and abutments, and it is a new idea that walls cannot be built with stone suitable for bridge work.

One great advantage the Panama route has over any other is the facilities it has for obtaining men and supplies, and their prompt and rapid distribution over the line of work. With regular lines of steamers to Aspinwall and Panama, any and all supplies are at all times readily obtained, and the railroad built to distribute them.

With his figures for the quantities of excavation for a tide-water canal on the Panama route, as only exceeding the lock canal on the Nicaragua route by 4½ per cent., we need not seek further for reasons for not giving quantities on a lock canal on the Panama route.

Colonel Totten built the canal of the Dique between the Magdalena river and Carthagena, also the Panama Railroad, with which work he was connected for twenty years. He should know the cost of work in

the tropics, and the advantages furnished to parties building a canal on the Panama route by the railroad across the Isthmus at this point.

He estimates the cost of a lock canal on the Panama route with a width of bottom in earth of 72 feet, and in rock of 80 feet; slopes in earth 1 to 1, with walls for protecting slopes, and slopes in rock ½ to 1, and with 28 feet depth of water, at $83 381 110. He estimates the same quantities, at Mr. Menocal's prices, at $42 364 248.

The kind of canal to be built is to be decided by those who build it, not by us here. The cost must, of course, enter into the question of choice, but as expressed in the Paris Congress, a canal without locks will be preferred at a very large cost over one with locks. A short canal is to be preferred at a largely increased cost over a long one. If we now combine the two advantages of a short canal without locks, it is incomparatively to be preferred to a long canal with locks.

The question whether any other than a tidal canal shall be built is one of great moment, and we must not be carried away with the statements of what can be done with a canal with a depth of 26 feet of water and with locks of 400 feet in length.

Steam transportation has been introduced in the last forty years, and has already revolutionized the commerce and business of the world. In former times, famines occurring, whole provinces were decimated. Now, a scarcity occurring in England, the Mississippi valley sends her crops by the railroad to the ocean, where steamers promptly deliver it at the desired ports. Russia aids, by her yet few roads, in delivering her crops on the Black Sea and the Baltic, to be forwarded by steamers, while California, Oregon and Washington Territory send by sail around Cape Horn, they yet waiting the great Inter-oceanic channel yet to be made across the Isthmus of Darien for steam transportation. Almost as great difference now exists in ocean transportation between the iron propeller, with its many water-tight compartments, and the old method of conveyance by sail, as exists between the transportation by coach and wagon and the railroad. Economy in transportation on the ocean is steadily being reached by the increased carrying capacity of the steamers, and the skill developed in generating and utilizing the powers of steam. Very many of our steamers leaving New York for Europe are over 430 feet in length, and drawing 26 feet of water loaded, and others are being built of over 500 feet in length. Is it a wise or far-seeing policy that shall now, in this age of progress, with steamships making such strides

in their carrying capacity, build a canal of such limited capacity as is proposed on the Nicaragua route, and thus limit the market of the States bordering on the Pacific. I do not believe that it is.

There is another point I wish to call to the attention of the Society, and which I have not heard dwelt upon, that is, that a canal across the Isthmus at Panama, while it will as well accommodate the business from the Atlantic ports, will, at its terminus at Panama, much better aid the trade between the Atlantic ports and the west coast of South America. Most of that trade now goes around Cape Horn, from which point it is as near Europe as New York.

The travel and light goods between the Atlantic and Pacific coasts of North America will be carried by rail across the continent. We have now one railroad completed, and three others in rapid progress toward completion. Canada has one in progress, and in a very few years Mexico, Honduras and Costa Rica will have completed roads, now in progress of construction.

What the steamer requires is the open sea, and when that cannot be obtained, a short canal, broad and deep, and without locks.

Whether it shall cost one hundred or two hundred millions of dollars is of no moment. If built in the proper manner, with wide channel and free from locks, its business will astonish the world by its magnitude, and its success, as a monetary investment, will be only limited by the judgment and conscience of those who control it.

Discussion by Charles D. Ward.

I will not attempt to discuss the general question of where the canal should be located, thinking more surveys are necessary before that can be done intelligently, but confine my remarks to the proposed canal with locks, from Colon to Panama, described in Mr. Menocal's paper, and more fully in the report of Commander Lull.

The question in my mind is, have they proposed the best plan for the canal on that route. Have they not possibly been frightened by the great rise of the river in floods, and without due consideration of the subject, taken it for granted that the Chagres River *must* be crossed by a *viaduct.*

I think it very feasible to dam the river and cross in slack water, and thereby save the viaduct and lower the summit level forty feet.

The bottom of the Chagres valley is so narrow that in floods the

river rises thirty-six feet, and attains a width of 1 500 feet, with a sectional area of 15 000 square feet. These figures give an *average* depth of water of but *ten feet*, which shows that if a dam was built with an overfall 1 500 feet long you might expect ten feet depth of water to pass over it. But Commander Lull states in his report :

"The extreme height attained by the water in time of freshets is due, to a *considerable extent*, to the backing up of the water from below, and could be *very largely* prevented by clearing off the timber in the short bends of the river below."

We cannot say how much this back water helps to raise the river, but I think we can safely assume that the dam would reduce the extreme rise in the river to *less than ten feet.*

The summit level would have the same elevation as the top of dam.

The reservoir formed by the dam would be ten miles long, and serve as an equalizing reservoir, and during floods would be entered from the summit level of the canal through guard locks, one on each side, which would be left open, of course, when there was no flood. Navigation across the reservoir would be easy, as the rate of flow of the current would be reduced from seven to three and a half miles per hour, the sectional area of the stream having been doubled by the dam.

I have estimated for a dam forty-four feet high, giving the summit level an elevation of eighty-four feet above tide water which is forty feet lower than Commander Lull's summit.

The advantages of my proposed plan I conceive to be: the saving of a feeder ten and one-fourth miles long, with syphon, dams, tunnels, &c.; an abundant supply of water, which is doubtful at the head of the feeder, but at the lower end of the reservoir we would have 120 square miles more of drainage area; saving the building of four locks and generally the time in passing through six less locks and finally save a viaduct 1 900 feet long and eighty-four feet high.

The rock cut at summit would have to be made forty feet deeper, and the dam built across the river, but from figures given in Commander Lull's report I have estimated that what would be saved on locks, feeder, aqueduct, &c., would pay for that extra work, and the cost of the two plans would be the same.

There would be but seventeen locks to pass through generally, but during floods nineteen. Commander Lull's Panama plan has twenty-five. The length, of course, would be the same in both.

Might not this plan, with its low summit level and few locks, be the happy medium between the expensive sea-level plans and the cheaper, but longer and more elevated routes, with a larger number of locks.

In conclusion, I would say that I should be very glad to hear the views of the engineers that are personally acquainted with the Chagres river, as to the practicability of putting in dams and using part of the river below Matachin for slack-water navigation.

Discussion by NATHAN APPLETON.

Being a delegate to the recent Congress at Paris on this subject, I desire to express my conviction that that Congress honestly attempted to find the best route for a canal. The delegates soon came to the conclusion that the best canal would be one without locks and without a tunnel. The general question of location was referred to the technical commission of the Congress, and the conclusion of that commission, as reported to the Congress, was the basis of the final decision. The matter wasnot hastened. It was impossible for so large a Congress to remain in Paris and devote a long time to this subject. And at the beginning it was hoped by the delegates that the matter would require but a few days. But before a conclusion was reached a full fortnight had passed.

The technical commission, on the basis of all the surveys and examinations at their disposal, many of these being made by the Government of the United States, came to the determination that the only place where they could recommend that a canal should be constructed was on what is known as the Panama route.

To designate the Nicaragua route as the American plan in opposition to all others would be unfair. American engineers had examined the Isthmus and found between the oceans the same impassable mountain except at Panama, and therefore there they built the successful railroad now in operation.

To the suggestion that the decisions of the Paris Congress had been unfairly influenced by M. de Lesseps personally, the reply is, first, that the character of the members of that Congress was such as to make such a thing impossible; and secondly, that the character of M. de Lesseps is such as to make it impossible that he should attempt to use any improper influence. He is a man with a world-wide reputation, and

my personal acquaintance with him has made me know that his reputation is well deserved. He is the soul of honor.

If, when he has examined the route at Panama, he finds that a canal cannot be built, then he will be the first man to say so to all the world. If, on the other hand, he finds that the decision of the Paris Congress is correct, he will take hold of the project with vigor, such as he showed in the construction of the Suez Canal, and he will push it to completion and success.

Discussion by S. F. Shelbourne.

The plans presented for the Nicaragua Canal provide for locks of 400 feet in length. The requirements of commerce, even in the present, and certainly in the future, will not be satisfied with that length; there are already many vessels that would not be able to pass through them. If the present plans should be enlarged, then comes in the question of much greater cost, greater water usage, and more difficulty of operation and expense of maintenance.

For a distance of over seven miles, just back of Greytown, this canal would pass through a series of swamps and lagoons. In this section there is a perfect net-work of trunks and stumps of trees embedded in the alluvial drift from above, and as this portion of the canal would be excavated on the sea level, and, therefore, under water, the cost would be largely increased above the estimates. Besides, also, in this portion the width of bottom and slopes of the excavation are entirely inadequate for permanence, and the excavated material, if put upon the banks, would have to be removed a considerable distance away from the edge of the slopes, so as to avoid, on account of its softness, anything like an attempt at an embankment. In fact, for this portion of the canal, the estimated excavation is something less than one-half what it should be to afford a proper working channel.

On the eastern division of the proposed canal there are enumerated twenty-five streams or small rivers, which at certain seasons become rushing torrents. It will be difficult to provide for and manage these streams while the work of construction is in progress. To furnish a permanent way for these streams, 12 cesspools and 13 culverts are contemplated, at an estimate of only $340,400, while for 16 culverts on the Panama route the same parties have estimated the sum of $18,331,343. The disproportion of these estimates seems most remarkable.

In the slack-water river navigation proposed for this canal, many of the sharp curves are wholly impracticable for even moderate-sized vessels under a slow movement, but no provision has been made in the estimates for any improvement in this respect.

As to the creation of a proposed harbor at Greytown by means of a jetty, it is clear that the same causes now operating would continue, and that an indefinite and continuous enlargement of the jetty would be requisite.

The prism of excavation for this canal at the bottom is altogether insufficient to allow two vessels of even moderate width and draught to pass each other without injury against the bottom of the slopes; so, too, the 7 miles of dredging at the entrance to Lake Nicaragua has been but meagerly and partially provided for, both as to width and depth.

But the heaviest items of deficiency are the estimates for the submarine and open rock cut excavations. There being nearly a million cubic yards of the former, and about 15 million cubic yards of the latter, to bring the estimates to a par with those for the San Blas route, there should be added to the cost for these two items alone $31,000,000.

When all these items of construction are taken into consideration, and the fact that an artificial harbor has also to be created at the Pacific end, it will be seen how entirely defective and delusive are the plans and estimates for this canal.

As to towage, it will be found requisite to tow sailing vessels for the whole 181 miles of the transit, and this expense for the Nicaragua route would be six times greater than for the same service on the San Blas route. So, too, the expense of operating the 21 locks of the Nicaragua route would be very great, and wholly extra, as compared with the San Blas route, involving a gang of men and costly machinery at each lock, so that, in fact, the cost of repair, operation and towage by the Nicaragua route would make a total sufficient to afford a handsome percentage of profit on the shorter and less expensive route by San Blas.

But the advocates of the Nicaragua scheme have assumed to reply that at least one tide-lock would be necessary both at San Blas and on the Panama route, and that, as ships pass locks in succession, one lock would afford as much obstruction and delay as twenty would. They have failed to consider that a tide-lock does not involve the same conditions as an ordinary lift-lock. Its gates may be sliding gates, with no necessity to be close fitting or water-tight, since the waters of the

Atlantic and Pacific can never be exhausted in balancing themselves alternately the one way and the other through such a lock ; and besides, while by Nicaragua one vessel only could pass at a time, a tide-lock on the Pacific end of the San Blas route could be so large as practically to amount to a basin, and pass through six to eight vessels at a time.

The objections which Mr. Menocal's paper urges against the San Blas route, relating to an assumed instability of the rock for the arch of the tunnel, I consider to be based on a misapprehension or a want of information as to the facts of the case, and his assumed illustrations are inapplicable and illogical. We know enough, indeed, about the character of the rock on this route to make it apparent that Mr. Menocal's fears on that score are largely imaginary.

Taking the Nicaragua route as a whole, with its conditions of length, its water-stairs of locks, with their liability to derangement, its want of natural harbors, its heavy items of maintenance and towage, it affords an exceedingly unpromising invitation to the shipping of the world. When, too, it is considered that the first cost of all this artificial construction, to be kept in order, would mount above a hundred million dollars, it may be foreseen that commerce would look long at the problem before finding a balance of advantage against its tolls and its dangers.

Discussion by Max E. Schmidt.

In Mr. Menocal's valuable paper occurs the following statement :

"It is evident the American Isthmus has been sufficiently explored to enable us to determine the difficulties that would have to be met in the construction of a ship canal at the several places pointed out as representing favorable indications."

This statement cannot be justly sustained by the remarks in the paper itself. Of the three routes treated, Mr. Menocal says of Lieut. Wyse's plan :

"This line is not one of actual location, but was traced on a map of the Isthmus between Colon and Panama, constructed from such information as could be obtained from the maps of the railroad, and the survey of Mr. Garella, made in 1843, for a canal with locks, on a location other than that adopted by Lieut. Wyse. The elevations of the ground, given

in the profile, were also obtained, as near as practicable, from the same source of information, and the figures are, therefore, to say the least, a rough representation of the natural conditions."

Of the San Blas route, the author says likewise :

" This line has not been surveyed throughout its length."

Again, the knowledge of the geological formation of the Isthmus, obtained from surface examination mainly, is known to be so deficient that the author himself necessarily admits into the wide range of "guessing" some of the most important calculations introduced into the estimates of probable cost of the canal *à niveau*. The Nicaragua route, and the route from Colon to Panama, for a canal with locks, seem, therefore, to be the only ones that have been sufficiently surveyed to warrant correctness of the estimates. But does this fact exclude the possibility of the existence of other routes, which a thorough survey would develop, to be more practicable for inter-oceanic transit than either the Nicaragua route or the canal with locks between Colon and Panama ?

It would be folly, to be sure, to believe in the mysterious hints thrown out by the natives as to the existence of an open pass]; but, the question is, *has* the Isthmus been sufficiently explored to justify the recommendation of any one of the different routes, and if, as it appears not, would it not be more essential to discuss the urgency of an exhaustive survey of the entire divide. Mr. Menocal's statement that it is *evident* the American Isthmus has been sufficiently explored belongs, therefore, to say the least, to the category of open questions.

I would like to see a few longitudinal sections of the chain of mountains called the Cordilleras. Recognizing the great importance of securing the lowest pass, with such sections the location of the summit-level of the canal or tunnel could be judiciously determined. Certainly, American engineers would not hesitate to obtain the necessary information.

Excluding the Peninsula of Yucatan, there is located between the Atrato and the Isthmus of Tehuantepec, a territory having a surface area of about 215 000 square miles. This territory is narrowly spread over a distance of nearly 1 600 miles in length, and constitutes what is called the American Isthmus. In this distance perhaps eight lines have been run from ocean to ocean, and a few additional ones from tide-level up, or partly up the divide. How much of the adjacent country has been seen by the parties who surveyed these lines ? Would it be wise to undertake the expenditure of such a vast amount of money, when per-

haps in later years posterity would discover a place where this same canal might have been built cheaper, better and shorter.

As to the details of the three projects treated in the paper, it would be interesting to hear something positive about the methods which are to be employed on the tunnels of the "*canaux à niveau.*" How is the large laboring force which will be required to be distributed to finish the work within any reasonable time? Are pits to be sunk in the line of the canal, and how are they to be drained?

It may be inferred from the large mean annual rain-fall, that numerous springs will be met with in the excavation of the tunnel. Mr. Menocal has laid bare the kernel of the problem by exposing the difficulties that will be encountered from the works becoming flooded.

It has been stated that many vessels afloat exceeded the dimensions of the locks proposed for the Nicarauga route. This is an important statement. If the vessels of the present day cannot be accommodated in the locks on this route where is the revenue to come from fifty years hence? The locks ought to be large enough to suit the ships of the future, for otherwise the canal which is now built to facilitate commerce will place a restriction upon the increase of tonnage which must be expected in the future. In this connection it would be interesting to know whether the summit water supply on the Nicarauga route can be so regulated as to be sufficient for lockages of 500 feet in length and 75 feet in width. This enlargement would require an addition of nearly 200 000 cubic feet of water for each lockage. If additional feeders have to be provided for, from what source can they be taken, and what will be their expense of construction? Again, the maintenance of the dredged channel in the lake may become an item of expense, and, under the proposition of a bottom width of only 80 feet for the 26-feet channel, the speed of the vessels, set down at ten miles per hour for lake navigation, seems too great to be safe. The length and duration of transit are of secondary importance, however. Whether 30, 45 or 181 miles long, and whether 6, 10 or 38 hours in transit, what do these figures amount to when compared with the time and distance required to circumnavigate the South American Continent? Safe and commodious harbors, safety in transit, and some guarantee for the safety of the capital by a permanent usefulness of the work, will insure the construction of this highway, sooner or later.

Discussion by Thomas J. Long.

For the purpose of obtaining more definite information concerning the size of vessels that may have to be accommodated by an inter-oceanic canal I have carefully compiled, from the Liverpool Registry of Steam Merchant Vessels for 1879–'80, tables which I think will be of value in any discussion of the canal question. The registry above referred to is the most complete and reliable record of the kind. The Great Eastern is not included in the table given below, on account of its exceptional size:

TABLE NO. I.

Registered Lengths of Vessels.	Number of Vessels.	Total Number.
Between 480 feet and 490 feet	1	1
" 470 " 480 "	0	1
" 460 " 470 "	1	2
" 450 " 460 "	3	5
" 440 " 450 "	3	8
" 430 " 440 "	6	14
" 420 " 430 "	10	24
" 410 " 420 "	7	31
" 400 " 410 "	20	51
" 390 " 400 "	18	69
" 380 " 390 "	32	101
" 375 " 380 "	23	124
" 370 " 375 "	9	133
" 360 " 370 "	48	181
" 350 " 360 "	68	249

Note.—The American Lloyds for 1878 gives a length of 400 feet or more to three vessels which are given less than 400 feet in the above table.

TABLE NO. II.

Registered Tonnage.	No. of Vessels.	Estimated Tonnage.	Total No. of Vessels.	Total Estimated Tonnage.
Between 5 000 and 6 000	7	38 500	7	38 500
" 4 000 " 5 000	40	180 000	47	218 500
" 3 000 " 4 000	164	574 000	211	792 500
" 2 500 " 3 000	143	393 250	354	1 185 750
" 2 000 " 2 500	279	627 750	633	1 813 500
" 1 500 " 2 000	614	1 074 500	1 247	2 888 000
" 1 200 " 1 500	543	733 050	1 790	3 621 050
" 1 000 " 1 200	471	518 100	2 261	4 139 150

TABLE NO. III.

"MERCHANT VESSELS OF THE WORLD."

(From "Bureau Veritas," quoted in Van Nostrand's Mag., Dec., '79.

No. of Steamers	5 897	Tonnage	6 173 935 =	30 per cent.
" Sailing Vessels	49 024	"	14 109 605 =	70 "
Total	54 921	"	20 283 540 =	100 "

Many of the vessels included in the above tables are engaged in the transatlantic trade; but there is a large number remaining which are engaged in the general carrying trade, many of which would, probably, take advantage of a canal across the Isthmus, if of sufficient size to accommodate them.

In Table I. there are 54 steamers (including those mentioned in the foot-note to the table) which are 400 feet or more in length, and could not, therefore, be passed through the locks of the Nicaragua Canal, if these were built of the dimensions given in the paper. Two of these are engaged in the trade between the United States and Japan and China, in the fleet of the Pacific Mail Company—namely, the City of Peking, 420 feet long, and the City of Tokio, 402 feet long.

But the registered length does not show the length of vessel which would be debarred from using a 400-foot lock, for we must remember that the registered length is measured on the water line, whereas the

length of vessel which can be accommodated in a lock must be measured on a line at a distance above the water line equal to the height of the top of the gate above the water in the lock when it is at its lowest level; a distance, in this case, equal to 5′ + 10′.3 = 15′.3. The length of a vessel measured on this line is always greater than the registered length, and the ratio of the difference to the registered length increases as the size of the vessel decreases. Thus, in the case of the City of Berlin, the longest vessel in the above table, the registered length is 488.6 feet, but the length measured as above is 500 feet. Measurements of vessels with prows of greater curvature would show a still greater difference. It is doubtful if many vessels of a greater registered length than 375 feet could be passed through a 400-feet lock, and for this reason 124 vessels in the above table would be excluded from the canal.

It is the opinion of those engaged in the carrying trade that merchandise can be carried more economically in large vessels than in small ones, and that the limit in size has not yet been attained. During the past year the Orient, 460 feet long, the Arizona, 452 feet long, and the Gallia, 430 feet long, have been launched; and during the coming year the Cunard Company will send out a steamer 500 feet long, 50 feet beam and 7 500 tons measurement ; and the Inman Company will follow with one 525 feet long and 53 feet beam. Other steamship companies say that they intend to increase their fleets by larger vessels. All of which tends to show that the Inter-Oceanic Canal Commission were mistaken when, in their report to the President in 1876, they stated, as a reason for keeping the length of lock in the Nicaragua route at 400 feet, that "the "canal should be built for the class of vessels best adapted to extended "navigation, which class would in general follow the routes of prevail-"ing winds. *Extreme length should be discouraged, as well as for a true "economy as for safety of passengers.*"

If the canal is to be one with locks, a length of 400 feet will certainly be inadequate; and the present demands of commerce, or, at least, those of the near future, require a length of at least 600 feet. This change would increase the cost of the locks by about fifty per cent.

Another point to be taken into consideration is the draught of the large steamers. Very many of those which have a length of 375 feet or more draw about 26 feet of water, and it is not uncommon for some of the larger ones to leave this port drawing nearly 27 feet. In view of this it is evident that a depth of 26 feet in a canal or lock will be

another hindrance to vessels passing through. If Rankine's rule be adopted the depth of the canal will be 1½ feet deeper than the greatest draught of vessels, which will give a depth of water of at least 28 feet.

A breadth of beam of 44 feet or upward is not at all uncommon in large steamers, and, as stated above, some of the steamers of the future will have a beam of more than 50 feet. Evidently, a greater width of canal is required than that given by Mr. Menocal.

It would seem, then, in view of the fact that in the carrying trade steam is taking the place of sails, and large vessels the place of small ones, that a canal which is to accommodate the trade of the near future, and which is to be built for the ships, and not the ships for it, will require a depth of at least 28 feet; and if there are to be locks they must not be less than 600 feet long.

From Tables II. and III. it will be seen that about twenty per cent. of the tonnage measurement of all the vessels in the world—both steam and sailing—is in vessels of over 1 000 tons measurement, and that it comprises about sixty-seven per cent. of the total tonnage measurement of the steamers. The question whether vessels of 1 000 tons and upward can be locked in twenty minutes, as estimated in Mr. Menocal's paper, becomes one of very great importance, and the figures given in the table will be of use to every engineer who may study the subject.

Discussion by Edward P. North.

It may seem premature, with the data in hand, to estimate on the total cost of an Inter-oceanic Canal; but this total cost is such an important factor in the practicability of any canal scheme, that it should not be neglected.

It is well known that in addition to the engineers' or absolute cost of any work, there are other expenses—some perfectly legitimate—which depend so largely on the honesty and discretion of the board of direction on the one hand, and on the confidence of the public in the scheme on the other, that it is almost impossible to correctly estimate them.

An analysis of the cost of the Suez shows that the two items were in round numbers—

Absolute cost	$48 000 000
Expenses of administration	50 000 000
Total	$98 000 000

As in the present case there are rival projects in the field, and no route is now known that does not present complications, which, though doubtless surmountable, will tend to alarm timid investors, and as the work is much further from the accumulated capital and low rate of interest of Europe, it may be assumed that even under Count de Lesseps' experienced guidance, these administrative expenses will amount to at least 115 per cent. in place of the 104 per cent. of the Suez Canal.

As a careful location has been made only on one route, and that is now generally admitted to require revision in the matter of curves, locks, &c., no estimate of the absolute cost can be advanced as more than a rough approximation, but the general impression seems to be that it will be in the neighborhood of $120 000 000; if to this $138 000 000 (115 per cent.) be added for administrative expenses, we will have the cost at completion $258 000 000.

It can hardly be expected that on the completion of this canal the routes of commerce will immediately change, and even if that were probable, the investors must wait for an increase born of the facilities afforded by the canal before they can hope to receive a satisfactory income from their expenditure.

As even a small railroad enterprise, shortly after completion, passes through the various phases of floating debts and ingeniously-named mortgages—if happily it escapes the hands of receivers, this canal, if ever built, must probably see its immense capital nearly if not quite doubled before its dividends can equal 15½ millions or 6 per cent. on the cost at completion.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(Vol. IX.—February, 1880.)

INTER-OCEANIC CANAL PROJECTS.*

DISCUSSIONS

By ASHBEL WELCH and JULIUS W. ADAMS.

Discussion by ASHBEL WELCH.

As Mr. Menocal has invited criticism of his paper, I shall give it freely, without any regard to what project it may make for or against. I do not propose to discuss the general subject outside of the paper, nor to go much off the Nicaragua route.

I shall not express any opinion as to the proper route for the inter-oceanic canal, for I have not sufficient data for forming an opinion; and I am not quite sure that anybody else has.

My conception of the province of this "Society of Civil Engineers"

* Inter-Oceanic Canal Projects, by A. G. Menocal. Vol. VIII. p. 311 (November, 1879). Discussions on the subject. Vol. IX. p. 1 (January, 1880).

is, to arrive at and disseminate, correct *engineering* conclusions from data laid before us. To make these conclusions of any value, they must be free, impartial, and cautiously drawn. They can then be applied wherever they are needed as guides. It is our duty to give such opinions to the public.

To attempt to decide other than engineering questions, would weaken the influence and impair the usefulness of this Society.

Canal making has been for many years one of the lost arts. While much of the whole engineering ability of the world has been directed to improvement in railroads, improvement in canals has been thought of but by few. Old forms and rules, and ideas and precedents, founded on experience under circumstances entirely different from ours, make up the little that is said in engineering books on the subject. To make a canal requires much more skill and care than to make a railroad.

The plan before us contemplates a water communication between the oceans of 181 miles in length, of which, in round numbers, one-third is through Lake Nicaragua, one-third from the outlet of the lake down the San Juan river, formed into a succession of small lakes by dams, and the rest by canals connecting all these lakes with each other and with the two oceans.

As far as I can judge from the data given, the locations and general plans are highly judicious ; especially diverting the turbid waters of the San Carlos, an affluent of the San Juan, away from the line of navigation, and leaving the valley of the San Juan, and carrying the canal across the country to a harbor remote from the mouth of any very large silt-bearing stream.

I am glad that I am able to say so much in favor of the general plan and route, because on so many points I am compelled to differ from Mr. Menocal, in some very widely.

It is proposed to make the canal 72 feet wide at bottom, 26 feet deep, with slopes of 1½ to 1, and with locks, 400 feet long between gates, and 70 feet wide.

This depth would not, considering bars and irregularities always liable to occur, safely and practically allow sharp vessels of much over 24 feet draft to navigate it, nor vessels with but little dead rise with as much as 24 feet. The demands of ocean navigation are already requiring vessels of 26 feet draft, and this canal ought to be 28 feet deep.

In addition to this, the bottom, where practicable, should be dished

so as to be 2 feet deeper at the centre. This costs but little, and not only gives more room for the counterflow of the water around the vessel and under its bottom, just where room is wanted, but as a vessel always inclines towards the deepest water, it keeps her in the middle of the canal.

When the bottom is soft the rush of water under a vessel from the stem and keel, each way sideways, carries the mud from the centre of the canal, and piles it up along the angles of the bottom and sides. The dirt thus formed shows what nature requires.

The width proposed, 72 feet, barely allows two vessels of 42 feet beam and 24 feet draft to pass each other, and then only at great risk of scraping off their copper, or their rust preventing paint.

The slopes in earth are proposed to be 1½ to 1. In most cases that I know of, this has been found too steep, if the canal is much used; unless its banks are walled or paved. It is not safe to calculate for less than 2 to 1 below top water line.

The navigation of this canal will be largely by steamers. They wear down the banks, not because they go by steam, but because they go so fast. Their immersed midship section may be one-third of that of the water prism of the canal. Then the average counterflow of the water has half the velocity of the vessel, but under its bottom much more.

I have found that a boat of only one-fifth of the section of the canal, towed by a locomotive six or seven miles an hour, made sufficient commotion in the water to wear down the banks very rapidly.

The minimum curvature in the canal proposed by the Paris Congress, a mile radius, is unnecesarily large, if it is to be attained only at great cost. On the Raritan river, while passenger steamboats ran, they used to go around bends of radius not over four times their length, with three or four times the speed that vessels will go on this canal.

In a curve, the canal should be widened to an extent equal to the versed sine of the arc cut off by the length of the longest vessel.

Where it costs no more, the canal should have extra width and depth.

Scouring sluices should be made in the canals on the San Juan, where silt-bearing water comes into it. I have found such of very great advantage.

In rock cuts it is proposed to commence at the bottom with slopes of 1½ to 1, and carry it up nearly half the depth of the canal, then perhaps ½ to 1, to top water. This narrows the canal at bottom to sixty feet, con-

tracts the water space just where it is wanted, and makes it almost certain that the bilge of every passing vessel will strike the rock. The rock below top water should be cut down as steep as possible. The cost is small in comparison with the whole cost of the cut, in deep cut increasing it only five or six per cent.; while the advantage over the form proposed is immense. It is difficult to believe that the section shown is not a mistake of the engraver.

G. W. Pearsons.—An experience of several years' handling of vessels passing the Welland and St. Lawrence canals, shows that any bottom of rock that can possibly touch the bilges of vessels, is not only damaging but destructive, and that no vessel can touch any rock surface with any portion of the submerged hull and pass out of the canal with assurance of safety.

Ashbel Welch.—It is proposed to make the lock chambers 400 feet long. Steamers of more than that length are now in use, and the tendency is to make them longer. For such long voyages as will be made by ships passing through this canal large ships are most advantageous.

If it is worth while to make an inter-oceanic canal at all, it is worth while to make it big enough to answer the purpose. If the canal is ever made, the locks will probably have 500 feet length of chamber; and it is better to calculate for that at once.

This paper and the Paris Congress seem to assume that the locks of the same series should all have the same lift. In this case that is quite unimportant.

In most cases locks have been built where it is an object to save water, and so the same lockfull that passes a boat through one lock, is just sufficient, if the locks are alike, to pass it through the next, and so on through all. If unequal, the difference between one lockfull and another is commonly wasted. And so an inexorable rule seems to have been adopted, that locks connecting successive levels must always have the same lift.

In this case there is an abundance of water to use and to waste; and all that may be wasted by inequality of lift, can be passed down the canal without inconvenient increase of current.

Another consideration which led to this rule of uniform lift, was to secure uniformity in time of passage, so as to avoid accumulation of boats at the deepest and therefore slowest locks.

This is a controlling consideration where the locks are like those I

once saw on the canal along the Meuse, above Liege. The lock was filled by one small wicket; and my recollection is, that it took a full quarter of an hour to fill it. The locks I am most familiar with, perhaps four times as large as that, are filled in two minutes.

To fill a lock of 20-feet lift takes less than 50 per cent. longer than to fill one of 10-feet lift, and it can be done as safely, provided proper arrangements are made to secure the vessel. A lock of 20-feet lift would not cost over 50 per cent. more than one of 10-feet lift. The time lost by a vessel in passing a lock of 20-feet lift, would be but little more than half as much as that lost in passing two locks of 10-feet lift. It is not the filling and emptying, but getting in and out, that uses up the time, and that is the same in one lock as in the other.

I would put in locks of 20-feet lift on this canal, or even more, in all cases where the ground would admit of it.

It is proper that I should fortify my position by facts within my own knowledge. I once built a lock 220 feet long at Chesapeake City, on the inland water route between New York and Baltimore, of 16-feet lift. As the water had to be pumped up from the river below, I made a water-saving basin along side of it, eight times the area of the lock. It has been in successful operation for more than a quarter of a century, the basin saving nearly half the water. I was most unmercifully laughed at by a learned and able engineer who lived near the place (the same who laid out the rectangular part of the City of New York) for making a water-saving basin, a contrivance that had long before been exploded in Europe, and never used in this country. But, though violating an accepted rule, it succeeded; and has ever since saved several thousand dollars a year.

The reason why the contrivance failed in Europe was, that the basins, and the openings into them, were not big enough.

Many things given up as failures in one age or country become successes in another, by different circumstances, by improvement in subsidiary arts, or by avoiding former mistakes.

My old friend, Edwin A. Douglas, built locks on the Lehigh, of 30-feet lift, which worked safely and rapidly. His locks of 27½-feet lift were emptied in 1½ minutes,

The feeling against locks has grown up where water was scarce, where, for want of proper appliances, it took a long time to operate

them, and where the handling of large vessels by hand or by animal power was slow and subject to accident.

To overcome this slowness and risk, I for many years had in contemplation the working of locks and handling the passing vessels by steam. I carried it out ten years ago on the Delaware and Raritan Canal. It increases the capacity of that canal fifty per cent., and accidents, previously not infrequent, are not now heard of.

I was surprised afterwards, on visiting Europe, not to find any such contrivance for handling heavy vessels at the docks, though in many cases they had hydraulic power at hand. I am told that they have since used it. It should by all means be adopted in this case.

The intense preference for an inter-oceanic canal without locks, at the sacrifice of every other consideration, is a traditional *sentiment*, not an *opinion* founded on reason and calculation in view of things as they now are. It would be as reasonable to insist on a railroad absolutely without curves. Where there is plenty of water, as in this case, locks are comparatively small objections, unless there are too many of them.

The precedent of the Suez Canal should have little influence here. There there was no water to feed locks, no soil that would hold the water if they had it, and no drainage into the canal. On the American Isthmus the circumstances are just the reverse.

Several details of the locks, as shown by the plans in Mr. Menocal's report, I should make very different. For example, the angles between the bottom and sides are rounded and filled in. This is dangerous to deep vessels with sharp bilge, and takes away water space just where it is important for easy movement of the vessel, and that without any expenditure of water. On the Erie Canal they filled up the angles, but at great cost they cut them out afterwards.

I would use timber foundations, after the American fashion, because cheaper and safer, especially in a country where earthquakes are liable to crack concrete.

The hollow quoins should be of timber, which I have found not only to be cheaper, but more easily repaired, and enabling the gate to move with much less friction than against stone or iron.

The locks should be faced with timber, the most elastic that can be got, in this case 6 inches thick. It is not only cheapest, but it costs less to maintain it than ordinary cut stone faces. And it is of great advantage in saving the vessels from injury. In old times when packet boats

carried passengers between Philadelphia and Pittsburgh, I was told that those running west of the mountain, where the locks had cut stone faces, lasted five years; east of the mountain, where they had wooden faces, eight years.

Mr. Menocal expects to fill his lock, $400' \times 70' \times 13'$ lift, in six minutes, through two pipes 5 feet in diameter, with an aggregate area of not quite 40 square feet. To fill such a lock through such pipes, if the head of 13 feet was constantly kept up, and there was no friction or resistance, would require nearly five and a-quarter minutes. But as the head is constantly decreasing, and a large allowance for friction and obstruction from turning right angles must be made, the real time would be eleven or twelve minutes.

The pipes should be 8 feet in diameter, so as to have an aggregate area of full 100 square feet, and allow the filling to continue rapid after the head is reduced. The area of the water prism should be enlarged above and below the lock, and should be maintained quite to the lock, so as to enable the vessels to move with the least possible resistance. The guides into the locks should here be floats, not wharves. And the filling and emptying pipes should debouch, not on or near the face of the lock as in Menocal's plan, but as far to one side as possible, so as to make the least possible commotion in the water where the vessels lie. The locks should be operated and the vessels handled and held safely by steam, not on the vessel but on land.

The locks are estimated to cost about $35 000 per foot lift. Add for 100 feet increased length of chamber, and 2 feet increased depth of water, and larger feed pipes, and for a heavy expense in pumping, sure to occur, but not allowed or sufficiently allowed for, $15 000, making $50 000 per foot lift. Probably, with good grouted rubble masonry, or perhaps concrete, it can be done for that, but not with fancy masonry.

Mr. Menocal supposes a vessel can be moved into or out of a lock in a minute and a half. Judging from my experience in moving heavy boats, I should say it would take six minutes safely to pull one in with steam, overcome the inertia, and secure it, and four minutes to overcome the inertia and pull it out with steam. The gates ought to be worked by steam in two or three minutes (one and a half each), and the lock should be filled or emptied in five minutes. Other delays are sure to occur, especially on entering the lock when other vessels are about passing. The time lost for each lock, including slowing up on approach-

ing the lock and getting way on leaving it, will probably average half an hour.

The dams proposed are sufficient to pass the maximum flow of water from the lake, but not to pass in addition the water that accumulates in the basin of the San Juan, between the lake and the mouth of the San Carlos. Judging from the map, this may contain 1 500 square miles. The rainfall in a single storm may possibly be a foot, as I have known it to be (within narrow limits) in this country. In such works as this, the most extreme case must be provided for. The dams should, when possible, extend from rock to rock.

The strategy of floods is, not to attack them in front, but to flank them. Mr. Menocal has marked his abutment walls, and banks from them to the highland, only 10 feet above the crest of the dam. With such drainage and such rains, the discharge may, in extraordinary cases, be 400 000 cubic feet per second, and then the water would rise about 18 feet over the crest of a dam 1 000 feet long. Then, with the guard banks only 10 feet high, the flood would sweep them away, and the most disastrous effects would follow. The dams should be in wide places.

On the slackwater navigation of the upper Lehigh the guard banks between the ends of the dams and the mountain sides were raised some 10 or 12 feet above the crests of the dams. Then, with a smaller area drained in proportion to the length of the dams, a flood came in 1862, swept away those banks, and the whole navigation was utterly ruined.

It may be a question whether timber crib dams should not be adopted, instead of stone or concrete. I know any European engineer would turn away with disgust from such a proposition. Col. Adams, last Wednesday evening, made or quoted the just remark, that the engineering of each country should be according to its own "genius" and resources. Now, the "genius" of Great Britain is for iron, of France for concrete, of America for timber. The dams on the upper Lehigh were of timber cribs, and when the floods swept everything else away, banks and walls and rocks of many tons weight, these wooden dams stood alone in the midst of the torrent uninjured.

Such dams, when always kept wet, as they can in this case from the steady flow of the lake, will last a long time, perhaps a century, and then only the upper part will require repair. Every dollar saved will (money being seven per cent., compounded every six months) become

almost $1 000 saved at the end of a century. So it is better to expend $900 then, than one dollar now.

The equalizing effect of the lake on the flow of the water, and its purifying effect, and the use of it to stop the flow of water during construction, are of immense advantage to the safety and economy of construction of the works on the San Juan, and a powerful argument in favor of that route.

Disregard of the "genius" and resources and methods of our own country, and following European precedents established under circumstances entirely different, account for the fact that some of our best-read engineers were in former times least successful.

In the slack-water pools and in the lake where not already deep enough, Mr. Menocal proposes to cut channels with slopes of 6 to 1. If the material will stand, it is better to have the slopes steeper ; a vessel coming against so flat a slope will stick fast—if steep, it will glance off.

Instead of so much excavation in the pools, making a rather imperfect and precarious navigation, it would be cheaper and better to raise the dams higher, or make the mouths of the canals lower down. Dredged channels fill up. The same cause that made the shoal is likely to make it there again. Jetties often only shift the difficulty to another place.

As Lake Nicaragua is too shallow for navigation, next its outlet, at the southeast end, it is proposed to raise the water 3 or 4 feet, and cut a channel several miles long in the bottom of the lake, so as to give 26 feet depth of water.

This depth is insufficient, even if the canal is no deeper. The depth would be diminished by a southeast wind, and without a considerable average depth under the keel a vessel would bump the bottom as she pitches or falls into the trough of the sea, the waves here, it is said, being almost like those of the ocean. The width of channel proposed by the Paris Congress is none too great.

The excavation for that width would, I infer from the data given, be somewhere about 10 000 000 cubic yards under water. Taking the chances of rock, it cannot be estimated to cost less than nearly as many millions of dollars.

Mr. Menocal, with apparent hesitation, suggested to the Paris Congress that the lake might be raised 3 feet more.

I should say, confidently, that the surface of the lake should be raised twelve or fifteen feet more. The excavation under water would then be

reduced to a few hundred thousand yards, and that near shore, with a saving, perhaps, of $8 000 000. It is a great deal easier to raise the top of a lake than it is to sink its bottom, if you have water enough, as you have here. I judge from the profile that the saving in the cut through the back bone of the continent—8 miles in length—would be about $2 000 000. This makes the saving by raising the lake 15 feet, $10 000 000. The annual interest on this, at 7 per cent. (and that is quite as low as you can expect to get money for this project), is $700 000.

On the other hand, you have 30 feet more of lockage, 15 feet on each side of the lake ; which, at $50 000 per foot, will cost $1 500 000. The additional height of dam and guard banks may cost half a million ; making in all $2 000 000.

This at 7 per cent. is	$140 000
Maintenance and attendance of locks due to additional height, say	30 000
Detention of 4 000 vessels, one hour each, at $15 per hour	60 000
	$230 000

This from $700 000 leaves $470 000 net annual saving ; equal to a capital of about $6 700 000.

Of course these figures only express probabilities, but they are sufficient to call for a careful examination by some one possessing full and accurate information.

The only question is, whether much damage would be done by raising the lake so much. Judging from maps and the accounts we have, the damage would not be much. Suppose 300 square miles of land flooded, at half a dollar an acre, that would amount to only $96 000.

But this immediate saving by raising the lake is not the most important reason for raising it. The channel in the lake will fill up. Mr. Menocal finds much mud in the bottom of the lake. The same causes that put it and spread it there, will spread it there again. The piling up of the water by the trade winds, on the western shore, and its frequent reflux (which at one time led to the belief that there were tides on the lake), must cause currents along the bottom across the lake, and so tend to fill up the channel with mud.

But beyond even this, it is all important that vessels should have the whole open lake to sail in. In storms that are said to raise waves like those of the ocean, it would be very difficult to keep in a narrow channel.

A sailing vessel caught by a head wind in such a channel could not beat, and would be very likely to get aground.

Where a channel is unavoidable, the middle should be deepest, so as to give vessels a tendency to keep in the middle.

Mr. Menocal's estimate of the time required to pass through the canal is 38½ hours. That may be done with light steamers. Very heavy vessels will probably require twice as long.

Mr. Menocal makes the very incautious remark, that he sees no reason why the speed on the lake and river should not be as great as on the ocean. A North River pilot finds a great difference in his speed, whether he has 10 feet or 50 feet under his bottom.

Mr. Menocal estimates the cost of this work at a little over fifty millions. With the data before us, no man can tell what it will cost; but it is certain that it will cost much more than this estimate.

Few engineers in this generation would estimate canal work high enough. Items of the same name cost much more in canal than in railroad work. The movement is greater by human or animal power, the materials must be sorted more carefully, temporary railroads are not so readily used, and commonly the situation is lower and consequently the work much wetter. "Pumping and bailing" is always a heavy item, often a fearful one.

Mr. Menocal estimates rock at from $1.25 to $1.50 per cubic yard, it being, as far as we know, mostly granite and trap. If it were in a railroad hill-side cut, where after being blasted it could be moved a few feet and tumbled down the side hill, this might be a good big price. As it is on this canal, where much of it must be raised from 30 to 160 feet and then carried off quite a distance to get room and piled, and this done only with expensive machinery, requiring to be often and expensively moved, and as this trap-rock may be almost as hard as pig-iron, I should add at least a dollar a yard; making an addition of $15 000 000 to the estimate.

The earth excavation is estimated at 35 cents. On account of the same expensive hauling and carrying off and piling up as the rock, and as much of it will be wet, I would add 25 cents per yard to this, making an increase in the estimate of $8 000 000.

Embankment is estimated at 10 cents. Considering that to hold water under 26 to 30 feet head, only carefully selected water-tight earth will answer, and that carefully put in, in layers not over 2 feet thick (not any

kind of material tumbled down a high breast from a temporary railroad as in making a railroad bank), and as the banks are too narrow for such a head, I should add 25 cents per yard to this item; adding nearly $2 000 000 to the estimate, and this allows nothing for puddling.

The locks overcoming 212 feet are estimated at about $7 000 000. For the size and plan I think this is a fair estimate. But I would increase the amount of lockage to 242 feet, and the cost to $50 000 per foot lift, making the whole $12 100 000. From this deduct the saving out of the estimate (not the saving as I should estimate) by raising the lake, say $4 600 000, and we have $8 000 000. So taking the balance between these, the estimate is increased $1 000 000.

To do the work in any reasonable time, 100 large steam pumps will probably be required, and must be kept in operation for years, many of them night and day. I should add at least a million to the estimate for this item.

These additions bring the estimate up to nearly $80 000 000.

As I never heard of a canal estimate that came anywhere near the cost, and considering the unhealthiness of the climate (the workmen there will not have Capt. Lull with the whole power of the government to enforce total abstinence), the necessity of importing labor, provisions, tools and some of the materials from a long distance, heavy storms and consequent interruptions, probable quicksands in earth cuts, probable hardpan or cemented gravel, &c., probable damage by floods while the work is unfinished and unprotected, the necessity for a large amount of protection walls, slope walls and paving which the estimate seems entirely to overlook, the great loss on machinery and tools, and the dwellings for the hands, I should add at least 25 per cent. for unknown or unestimated items and contingencies, bringing the estimate up to a round $100 000 000.

If it is done by the government and gets into politics, add at least 50 per cent.

If it takes 5 years to finish the work, and $20 000 000 are paid over at the beginning of each year, the interest during construction (at 7 per cent., compounded every six months) will be twenty-three millions and a half; if $12 500 000 every 8 years, about 38 millions; if $10 000 000 every 10 years, nearly 49 millions.

This shows the propriety of getting thoroughly ready before beginning to spend large sums of money. The location should be definitely made, the ground and rocks, and the lake and river bottoms thoroughly

explored by pits and borings where necessary, the plans and specifications fully drawn out in detail and printed, the kind and amount of the necessary machinery ascertained, and the legislation and right of way settled, so as to have no delay when the work is once begun.

When the character of work is doubtful, reliable contractors will take it only at prices that will cover the risk. If it turns out easy they pocket the difference between the supposed and actual cost, but if it turns out worse, then not the contractor but the owners of the works will lose the difference. So those owners should remove all doubt.

The conclusions I have arrived at, and the estimates I have made, are mainly from the papers before us. Other and further information might change or modify many of them very much.

Great as is the undertaking to build the Nicaragua Canal, it is mere child's play, compared with the attempt to make a thorough cut through the valley of the Chagres, with its two and twenty rivers, which at times become so many deluges.

The opening of a canal across the great American Isthmus would be of great advantage to this country and to the world. Not only commerce would be benefited, but it would add another tendency towards the assimilation, the civilization and the christianization of mankind. But don't let us go into it without looking the risks and difficulties full in the face. Let us carefully and honestly count the cost. Let us take care not to allow those acting under our advice to place themselves in the predicament of the man who began to build, and was not able to finish.

Discussion by Julius W. Adams.

In response to the request of the officers of the Society, I have the honor to address you on the subject of the inter-oceanic transit of the American Isthmus.

Some ten years since I had occasion to read a paper before the Society, advocating the construction of a ship canal at the Isthmus of Tehuantepec, rather than at Panama, not on the score of its cheaper construction, but entirely in the interest of American commerce, pointing to the necessity of such canal debouching into the Mexican gulf, in the

interest of our domestic commerce, instead of its approaches being favorable to foreign commerce and domination by foreign guns, as would be the case if the transit were made at any other of the points which have been proposed than the Isthmus of Tehuantepec.

The subject was looked upon then as something far in the future, if indeed it had any merits as a practical problem, but it resulted in a resolution of the Society, of date March 16th, 1870, calling the attention of Congress to the need of a more thorough examination of the Tehuantepec Isthmus, and led, it is believed, to an appropriation by Congress to test by survey the practicability or non-practicability of constructing a ship canal at that Isthmus, and the survey was made under the orders of Commander Shufeldt, of the U. S. Navy, and Professor Fuertes, a member of this Society, was the chief Civil Engineer of the expedition. It resulted in a report that 172 800 000 cubic feet of water daily could be relied upon in the dryest season to feed the summit level, and that no impediment whatever existed to the construction of a ship canal. The sufficency of this quantity of water to the wants of a ship canal, is shown very conclusively, and with proper detail, by Mr. Fuertes, in a manner which admits of no cavil, and that making all needful allowance, in accordance with experience elsewhere, for the loss by evaporation, filtration, and leakage, there remains an ample water supply for the lockage of a daily traffic, amounting to 20 000 tons, and he gives his opinion to the effect that the supply would furnish water to the extent daily, if need be, for a traffic of 30 000 tons. This sufficiency of water confirmed the statements made by Mr. Moro in 1844, as the result of his examination.

You are all sufficiently impressed with the importance of an interoceanic canal through the American Isthmus somewhere between North and South America, for the advancement of commerce, and folios have been written, from the time of Columbus to the present day, on the benefits to be anticipated from the completion of such an enterprise to the world at large, which, before this audience, need only be referred to, without wasting time upon a consideration of them, but there *is* a view of the question which is not quite so hackneyed, and which it well becomes the members of this Society to carefully consider before committing themselves to the support of either of the schemes which have occupied the press for some time past, and this is the *American*, as distinct from the European side of the question, and which has been very much

lost sight of in the glamour attending the proposed "grand monumental structure" of the age. It is to this *American* view of the needs of *American* commerce that I propose as briefly as possible to call your attention.

It will be perceived in reviewing the proceedings of the Paris Congress, so called, that the *foreign* idea centered upon Panama, as the proper point at which to construct an *international* canal (which expresses something more than a merely *inter-oceanic* transit), and if not an *international*, then an inter-oceanic as near as possible to the Isthmus of Darien, and for this M. Ferdinand de Lesseps is the head and front. A canal with locks is not monumental enough for his ambition however, and if a system of locks is finally agreed upon as necessary, his interest in the subject will be materially lessened, if it does not vanish entirely.

Such of you as have informed yourselves of the precise character of the obstructions encountered in the construction of the Suez Canal, need not be told that M. de Lesseps is a man of ability and energy; and he may be a very proper man to direct such an enterprise as the one before him, but if he be, it cannot be inferred from anything he has done at Suez. Everything connected with carrying out the scheme of a through cut at Panama is so totally and entirely at variance with his experience heretofore, that success in the first mentioned is no guarantee whatever that he has grasped the difficulties of the latter. His visit to Panama may, or it may not, open his eyes; in either event, however, the result will be the same. That is to say, we feel well assured that such a canal will never be built, for the simple reason that Asiatic-European commerce alone will not pay a return on the necessary investment, whilst American commerce can be more economically provided for by an American route, as will be seen.

While in the Congress at Paris, foreign opinion was largely in favor of the Panama route, yet sensible men were to be found among them to admit of the *possibility* that perhaps nature will forbid of a *commercially* successful ship canal being built and sustained across the "narrow lands" of the continent further south than the Nicaraguan Isthmus, in which case their assent can be had to that; but not a foreigner could be found among them to entertain the idea for a moment of the feasibility of the Tehuantepec canal! And why was this? All that had been accomplished in the examination of the Tehuantepec Isthmus was known to them. The President of the latter company had, in 1871, appointed a Commission of Engineers to visit the water-ways of Europe, and from an

examination of existing works report upon the merits of that line for a ship canal. He had applied to the American Government for the appointment of an Engineer to be attached to that commission, and Gen. J. G. Barnard, of the Corps of Engineers, U. S. A., had been detailed for that service, and visited Europe as one of the commission which subsequently reported upon the Tehuantepec ship canal project as without doubt the simplest and cheapest line yet suggested for such a purpose. This report, printed in October, 1871, was known to *some* of the members of the Congress, possibly to all.

The objection to the Tehuantepec line could not have arisen from the fact of lift-locks being required on that route, for the chief objection to locks (aside from the expense) is presumably in the loss of time which they would occasion in transit, and the Nicaragua route, with twenty-one locks, would admit of comparison with other lines having a greater number of locks, providing *that* circumstance was compensated for by other and superior advantages, the difference in the amount of lockage in the two cases, being measured by *hours* merely of increased time of transit. No ; the objection to the more northerly route grows out of the fact that the Tehuantepec will be an *American* canal, first and foremost; and, while it might accordingly be of world-wide usefulness, its construction would give an undue preponderance to the rapidly-growing commercial supremacy of the Great Republic, and tend to nullify the present existing advantages possessed by the commercial nations of Europe, in competition with this country for the commerce of her *own* ports, as well as that legitimately hers by reason of her geographical position.

It is believed that evidence exists in the Department of State at Washington showing that the resident English Minister in Mexico actively and personally exerted himself with members of the Mexican Congress to procure the rejection of the Tehuantepec Treaty of 1851 ; and it is well known that the presumed antagonism in Mexico to the Americans of the North is not of native growth, but has its rise in the jealousy of resident German and English merchants.

And not a dollar could be had in England for the construction of a canal at Tehuantepec unless controlled exclusively by English capital and under her protectorate.

The geographical position of the United States calls for the construction of an *American* ship canal for the ameliorization of American com-

merce, and to strengthen the prestige which rightfully belongs to this country when it is the question to improve her own water-ways.

It is all very well to *talk* of the progress of mankind, and the more liberal policy which should obtain in the intercourse between nations, and to refer to the broader views of national reciprocity which should prevail in this enlightened age, but principles of philanthropy never will be permitted to control in matters of trade and commerce, and until the advent of the millenium, governments, while extending even-handed *justice* to all, will always rightfully aim to secure the material prosperity of their own people.

You have heard of the Monroe doctrine, as enunciated briefly, thus: "No more European settlements on this continent." To this we would add, what by fair inference it embraces: "No European partnership or co-protectorate in regard to *our* Isthmian ways and inter-oceanic communications." These ways, if necessarily opening into the Carribean Sea, are even then essential to a successful prosecution of our commerce with the South Seas. If they open into the Gulf of Mexico, they are domestic to ourselves. The desire of making the Gulf of Mexico a closed American sea is as natural to us as a similar policy to other powers in regard to the Black Sea, the Caspian, the Zuyder Zee, and others, and as Cuba is the key to the outlets of this sea, it becomes an inevitable destiny to acquire or to attain a Gibraltar on its shores in order that foreign fleets shall not interrupt our domestic commerce. The older governments of Europe affect to be startled at this enunciation of American policy, as though it were a new idea; but it is not. England openly avowed the principle, when she secured and held by the strong hand Gibraltar, Malta, and Aden in the Red Sea, and now Cyprus as on the route of her Indian trade. There is no more reason why foreign nations should be allowed to guarantee the neutrality of an American thoroughfare than that the United States should be a party to defend the British Channel, the Straits of Gibraltar, or the Isthmus of Suez.

In attempting to sketch the broad outlines which indicate the *where* of this American canal, I shall avail myself freely of the labor of others, and I am particularly indebted to a volume by Mr. Henry Stuckle, published in New York in 1870, for the tables of distances between ports, as well as for the views which he has so ably expressed in the advocacy of the line of transit, the merits of which I wish to press upon your attention.

Lieutenant Maury, in a letter written to a member of Congress some

twenty years ago on this subject says : "Owing to the course of winds, the direction of currents, and other physical circumstances, British merchants are ten days sail and upwards nearer than we are to all the markets of the world, except those of the Caribbean Sea and Gulf of Mexico. They are next door to all the markets of Europe, to Brazil, to Cape Horn, to the Cape of Good Hope ; and, consequently, to all ports beyond them, they are practically some ten or fifteen days' sail nearer than we are. A vessel from the United States, bound to the southern hemisphere, first sails nearly an east course until she arrives in the vicinity of the Azores and Canary Islands. She then puts her head south for the first time. Now, while the American vessel is sailing this route, the English vessel that sailed on the same day, for the same market, has passed those islands and is far on her way, for the reason that the Cape Verde Islands are some ten or fifteen days nearer to England than to America ; England is that much nearer to the southern hemisphere ; for vessels generally, whether from the United States or from England, are in the habit of passing by these islands in their way thither."

But it is not to meet the requirements of an European or an Asiatico-European commerce that a transit through the American Isthmus is to-day demanded (in times back it was otherwise), but, on the contrary, it is now mainly for *American commerce, in America*, and between American ports, and their commercial connections with the East, that such a canal is desirable, if not indispensable.

Our national territory has extended to the shores of the Pacific, and is now bounded on the south by the Gulf of California and the Rio Grande. Communication between our ports on the Atlantic and those of the Pacific requires protracted voyages. The distance from New York to San Francisco, for example, is over fourteen thousand nautical miles, by sea. The moment we are able to penetrate the Isthmus we have cleft America in twain, and we can pass from the north shores on the Atlantic to the corresponding coasts of the Pacific, without needing to descend to the fifty-fifth degree of south latitude. This will be the first great advantage, and the most important to the United States, which will be realized by the establishment of a water transit between the coasts, more available than any railway. There is here a great question, commercial, political, social, and economical, which is so clearly apparent as scarcely to require elucidation ; its statement alone sufficiently sets forth its importance.

In looking for the *where* we can best cross the continent, the point which first arrests our attention is the Isthmus of Tehuantepec, which is only 500 miles from our southern frontier at the Rio Grande, in Texas, and is accessible by means of the Gulf of Mexico, which is an inland sea, in a sense; and in the improvements of river navigation the shipping from our interior commercial centres will be able to extend their voyages to the coast, thus virtually emptying the Mississippi River into the Pacific Ocean.

If we examine the map it will be seen that this isthmus is the most feasible point at which an inter-oceanic communication can be had, whether we consider it especially in reference to the United States alone, or to the other American and European and Asiatic countries. From Europe or the United States to the Pacific it is the shortest route of any either now in operation or at present contemplated. This is exhibited in the following table, showing the respective distances from England, New York, and New Orleans to the port of San Francisco, in California, by the routes of Panama and Tehuantepec compared with the voyages from the same places round Cape Horn, and showing also the distance each would respectively save by traversing the American Isthmus:

Voyage to San Francisco, California	Round Cape Horn.	Via Panama.	Via Tehuantepec.	Dif. in favor Tehuantepec.
From.	Stat. Miles.	Stat. Miles.	Stat. Miles.	Stat. Miles.
England (Liverpool)	15 710	8 607	7 476	1 131
New York	16 360	6 218	4 741	1 477
New Orleans	16 500	5 718	3 384	2 334

Saved by	Distance Saved Via Panama.	Distance Saved Via Tehuantepec.	
England	7 103	8 234	1 131
New York	10 142	11 619	1 477
New Orleans	10 782	13 116	2 334

From "*The Tehuantepec Railway, its location, features, and advantages under the La Sere Grant*, 1869."

In order to complete the above table, so far as it concerns our trade

with California, we present a comparative detailed table of distance and time for voyages from New York and New Orleans to San Francisco by the two routes, according to the statements of distances (in statute miles) in the "*Memoir on Ocean Routes*," published in 1857, by Captain F. J. Cram.

The time required in each voyage, as indicated, including the delays rendered necessary by the discharge and reshipment of cargoes, is calculated from the average figures presented by the *log-books* of the steamers, connecting with the Isthmus of Panama, on the two oceans :

New York to Aspinwall	2 392	miles	in	8	days.
Aspinwall, by railroad to Panama	51	"	"	1	day.
Panama to San Francisco	3 775	"	"	13	days.
Total for the route of Panama	6 218	"	"	22	"
New York to the Coatzacoalcos	2 275	"	"	8	"
Railroad across the Isthmus	162	"	"	1	day.
Isthmus to San Francisco	2 304	"	"	8	days.
Total for the route of Tehuantepec	4 741	"	"	17	"
Difference in favor of Tehuantepec	1 477	"	"	5	"

By adopting for the trip from New York to the Coatzacoalcos the route of Fernandina (Florida), the distance becomes reduced from 2 275 miles in 8 days to 2 160 miles in 7 days (according to the tables of distances furnished by the Bureau of Navigation, in the Navy Department at Washington), as follows :

New York to Fernandina	969	miles	in	3½	days.
Fernandina, by railroad, to Cedar Keys	154	"	"	1	"
Cedar Keys to the Coatzacoalcos	1 037	"	"	2½	"
Total	2 160	"	"	7	"

It follows that, taking into account the saving obtained by the Fer-

nandina route, the difference in favor of Tehuantepec is increased from 1 477 miles and five days to 1 592 miles and six days.

The further south we go in the United States, the more clearly evident become the advantages of the Tehuantepec route. New Orleans is but 918 miles from the mouth of the Coatzacoalcos, and twelve days suffice for the voyage from New Orleans to San Francisco, as follows :

New Orleans to the Coatzacoalcos	918 miles	in 3 days.
Railroad across the Isthmus	162 "	" 1 day.
Isthmus to San Francisco	2 304 "	" 8 days.
Total	3 384 "	" 12 "
The same trip via Panama requires	5 718 "	" 22 "
Difference in favor of Tehuantepec	2 334 "	" 10 "

Resume of Time of Voyages by the two Routes.

	Via Panama.	Via Tehuantepec.	Difference in favor of Tehuantepec.
New York to San Francisco	22	17	5 days.
New York by Fernandina to San Francisce....	—	16	6 "
New Orleans by Havana to San Francisco	22		
New Orleans to San Francisco		12	10 "

We have already seen that the geographical position of the Isthmus of Tehuantepec offers for the European trade with California, Japan and China an improvement of 1 131 miles.

The central part of our continent, which we call the Isthmus, extends from Tehauntepec to the main land of South America, with a length of about 1 500 miles.

If we imagine two canals, one at each extremity of this Isthmus, it is not strictly true that in making a voyage from a northeastern latitude to one corresponding in the northwest, and by taking the southern canal instead of the northern we should add twice the length of the Isthmus, or 3 000 miles to our voyage. Owing to the configuration of the land south of Cape Hatteras, and the location of the Antilles and their neighboring shoals, the navigator from the northeast—on the Atlantic side—compelled to approach the Isthmus in an oblique direction ; he does

not coast it from north to south. On the Pacific side the case is different; there, the sailor going from north to south, or from south to north, skirts the shores of Central America, and describes in his course a distance corresponding nearly to the length of the Isthmus. For these reasons, a difference of from 1 500 to 2 000 miles is all that is admitted in a voyage from New York to San Francisco in favor of the northern route. This difference, however, remains sufficiently formidable in a voyage of about 5 000 miles, supposing the existence of an inter-oceanic canal. For steam navigation the difference is naturally somewhat less.

In the table we have given, page 65, the difference in a voyage to San Francisco between the two routes of Panama and Tehuantepec, is estimated at 1 477 statute miles, from New York, and 1 131 from Europe, in favor of the latter. The distances are *estimated* for those portions of a route where no established steam lines exist. In the subject under discussion, however, the interests of the sailing marine have their full importance, as a great part of the commerce between the Atlantic and Pacific States, by reason of the nature of their cargoes, will be carried on in preference by sailing vessels. The difference in the distance to be run by the one route or the other has thus to be taken into account at its full value.

It may be stated approximately, that whatever route through the American Isthmus should be opened, it would at once command the trade between Europe and California, and our own trade with the west coast of America, west coast of Mexico, and the Pacific States. This is estimated at 1 500 000 tons, one-half of which is between the northwest and northeast of our continent, and one-fifth between the northwest of Europe and the northwest of America. Should we propose to impose upon two-thirds of our whole commercial movement above noted, an unnecessary detour of 1 500 miles by forcing it to cross at the southern rather than at the northern end of the Isthmus? Certainly no one would have the courage to advocate such a proposition, and yet the location of a ship canal at Panama aims to bring about precisely this most singular achievement.

In examining the above statement two leading ideas develop themselves. The first is, that the American canal (Tehuantepec) is destined to serve especially the commercial interests of America. Two-thirds of the commerce which is interested in the construction of this canal may be estimated as American.

The second point which becomes apparent is, that in providing first for the interest of American commerce in the location of the canal, those of all other parties are at the same time equally protected.

If we examine the position of this route with reference to the relations of our Atlantic ports and Europe with the western shore of South America, we find that Tehuantepec is over ten degrees to the north of Panama, and that freights leaving Tehuantepec for the south would be compelled to traverse the Pacific for the entire distance which separates Tehuantepec from Panama, in order to secure the same relative position as those transported via Panama. At first sight, this difference in the voyage to be made presents an apparent disadvantage, which has, nevertheless, no existence, for a very simple reason. Either the freights via Tehuantepec in this case, are bound from the Atlantic ports of the United States and from Europe for the western coast of South America, or they leave the ports of Peru and Chili for the Eastern United States and Europe. In the former case their Atlantic trip would be shortened by all the distance between Tehuantepec and Panama. It is, therefore, evident that they should run upon the Pacific the same additional distance as they would have run upon the Atlantic, in case they had been going by way of Panama. In the latter case the greater distance to be run on the Pacific in order to reach Tehuantepec, compared with the transit by Panama, is compensated by an equal distance saved on the Atlantic side. This refers, of course, to a movement from the northeast to the southwest, and the reverse.

The saving of time and money by the employment of a ship canal traversing our continent, with reference to the trade between our eastern and western shores, is almost beyond calculation, by reason of the geographical position of the Atlantic and Pacific States. The distance of 16 360 miles from New York to San Francisco, by way of the Cape, for example, will be reduced to 4 740 by canal, which, for the present, we suppose to be located at Tehuantepec. The voyage will, therefore, be reduced by 11 619 miles, and the duration 105 days—the sailing vessel requiring, say 150 days by the Cape and 45 days by the canal.

According to the estimated cost of a voyage to San Francisco the reduction in the duration of the voyage will secure an economy of $9 261 for a vessel with a crew of thirty men, and another saving of $4 042 in insurance and in interest on the capital presumed to be represented by the cargo. And the total saving for a single trip would be $13 300, which,

with reference to the tonnage, supposing the ship to be of 1 000 tons, would make a saving of $13 per ton, or $26 per ton for the round trip going and returning. Such an improvement in the conditions affecting our commercial relations with California when the inter-oceanic canal is opened, would cause a revolution in the supply of food and other domestic products to our great centres of population on the Atlantic coast.

This improvement would bring our manufactures and commercial centres in the Eastern States nearer to our Pacific possessions, with their increasing population, by distances measured by thousands of miles. And on the other hand, from San Francisco to Liverpool, the ship laden with our produce is now compelled to make a voyage of 15 710 statute miles, which would be reduced to 7 476 ; yet, notwithstanding this necessity, the agricultural products of the rich soil of our Pacific States can now compete with similar products in the European markets. What will these shipments become when forty-five days instead of 150 days shall suffice to bring them to the shores of the Atlantic, and what a feature in the agricultural development of the Pacific States will this shortened voyage to Europe offer. From California to the eastern coast of South America, as for example, to Rio Janeiro, we have to traverse a distance of 9 200 miles, being always under the necessity of doubling the Cape, whilst by way of the Isthmus the products of the Pacific States destined for Brazil would be conveyed 4 500 miles.

Passing from our internal commerce, and from the consideration of our agricultural exports to the question of importation and exchange, which has as yet hardly made a beginning with the western coast of South America, we immediately perceive the bearing of a water transit across the Isthmus. The new route (Tehuantepec) will bring our eastern ports exceptionally near to those of western South America, the commerce of which is at the present time almost all absorbed in Europe. We have actually 8 700 nautical miles to traverse in going from our Atlantic ports to Valparaiso, and 9 900 nautical miles to Callao. New York will not be further from these ports than England when the passage through the Isthmus shall be opened, and the voyage from our commercial metropolis to these ports will be reduced nearly *one-half* for the first and *two-thirds* for the second. In fact, the western coast of South America will be brought so near to our Atlantic ports that we shall, in part at least, supplant Europe in their commerce.

The following table, furnished by the Navy Department at Washing-

ton, shows the comparative distances from Europe to Australia and eastern Asia by way of the Suez Canal, and a canal across the American Isthmus :

	Via Suez.	*Via* American Isthmus.	In favor of Suez. Naut. miles.
From Liverpool to—			
Hong Kong	9 568	14 220	4 652
Shanghai	10 368	13 820	3 452
Yokohama	11 403	12 900	1 497
Melbourne	11 269	12 600	1 331

We need not observe that the distances themselves are not to be accepted as a final argument in a discussion which involves navigation in general. However we may regard these distances as a base of argument in speaking of steam vessels, we are compelled to admit other weighty considerations when we come to deal with sailing vessels. We are well aware that the region in which the trade winds are most reliable, corresponds with the American Isthmus. The trade-wind region extends on either side of the equator, on the Atlantic and Pacific, to the parallels of 30° north and 30° south latitude. The facility of availing of the trade winds by employing the American canal for sailing vessels between Asia and Europe, may doubtless attract a part of that trade to the American Isthmus ; but in view of the change which is taking place in the construction of sailing vessels, the tendency to substitute steam for sails in long voyages, and the special facilities offered by the Suez route for steam navigation, the utility of the American canal to the Asiatico-European trade must continue still problematical.

We give the following table of distances from New York to the two prominent ports of the western shore of South America, by way of the Cape, and by way of an inter-oceanic canal :

Ports.	By way of Cape Horn.	By way of an Isthmian Canal.	In favor of the inter-oceanic Canal. Naut. miles.
Valparaiso	8 720	5 000	3 720
Callao	9 920	3 700	6 220

This reduction would give us a marked advantage in competition with the maritime countries of Europe.

To render still more striking the effect of the location of the inter-oceanic canal at one point rather than the other, let us compare the results which would be attained by the two rival routes. For this purpose we give here tabular statements, prepared in the Hydrographic Office of the Bureau of Navigation, indicating the distances from New York and New Orleans to the principal ports concerned by way of a canal at Darien and of one at Tehuantepec. These tables give at the same time the distances *via* Cape Horn.

TABLE OF DISTANCES FROM NEW YORK.*

To	*Via* Cape Horn.	*Via* Isthmus of Darien.	*Via* Isthmus of Tehauntepec.	In favor of the Canal at Tehuantepec. Naut. miles.
San Francisco	14 200	5 300	4 400	900
Mazatlan	13 000	4 060	3 135	925
Melbourne	12 720	9 890	9 600	290
Honolulu	14 100	6 730	5 955	775
Yokohama	17 340	10 210	9 435	775
Shanghai	18 300	11 100	10 355	745
Hong Kong	19 000	11 500	10 755	745

TABLE OF DISTANCES FROM NEW ORLEANS.*

To	*Via* Cape Horn.	*Via* Isthmus of Darien.	*Via* Isthmus of Tehuantepec.	In favor of the Canal at Tehuantepec. Naut. miles.
San Francisco	14 500	4 650	3 070	1 580
Mazatlan	13 300	3 390	1 800	1 590
Melbourne	13 000	9 250	8 260	990
Honolulu	14 400	6 030	4 620	1 410
Yokohama	17 600	9 510	8 100	1 410
Shanghai	22 300	10 430	9 020	1 410
Hong Kong	19 300	10 830	9 400	1 430

* "In general the distances are measured on steam routes, when lines are established, and are approximately correct."—Observation by the Hydrographic Office to its tables.

We give now the respective distances from the Lizard to the prominent ports of eastern Asia by way of a canal at Darien and of one at Tehuantepec.

DISTANCES FROM LIVERPOOL TO EAST ASIA.

To	*Via* Isthmus of Darien.	*Via* Isthmus of Tehuantepec.	In favor of the Canal at Tehuantepec. Naut. miles.
Yokohama	12 900	12 400	500
Shanghai	13 820	13 320	500
Hong Kong	14 220	13 720	500

The Asiatico-European traffic through the American canal would certainly be inferior in amount to the trade which is directly interested in the construction of the proposed transit, and to whose especial convenience the canal should be adapted. In case the selection made of the location of the canal should not answer completely the requirements of foreign commerce, we could not hesitate on that account, as our own interests must first of all be protected; but when it is shown that the northern location gives not only an advantage to American commerce, but something to that of Europe also, we can but be the more strongly confirmed in our choice.

In commerce, all questions become affairs of arithmetic and figures. Without attempting in any case to make too elaborate an argument, let us calculate the loss to American commerce which would be caused by the adoption of the Darien route. We see by the calculation made of the expenses of a ship of a thousand tons, from New York to San Francisco, by way of the Cape and by way of the canal, that the latter are estimated at $6 843 for ship and cargo. If, in consequence of a detour occasioned by the location at Darien, this voyage of about 5 000 miles should be increased by 1 500, the cost of transportation, which is nearly in exact proportion to the duration of the voyage, would be augmented by at least one-fourth, say $1 710. This is for the commerce between New York and San Francisco, estimating it at only 500 000 tons, and if we represent this movement by five hundred vessels, averaging one thousand tons each, we find that the annual augmentation in the cost of

transportation would be $855 000, on account of the unnecessary detour. Estimating the shipping between California and Europe at only 200 000 tons, we have seen that for the trade of Europe with California the detour occasioned by a canal on the southern part of the Isthmus, is at least 1 000 miles. We therefore represent the cost of the detour to this branch of trade as one-fifth of the $6 843 mentioned above for the cost of a voyage of a sailing vessel over five thousand miles, say $1 368, and allowing for the given commercial movement of 200 000 tons, two hundred ships of one thousand tons average, we see that the increase of expenses would be $273 600. Adding this to the $855 000, we have the sum of $1 128 600 for the loss which the location of a canal in the southern part of the Isthmus would cause annually to our commerce. This is an under-estimate, without taking into account the loss to our Asiatic and other shipping, and the impossibility of bringing our Pacific fisheries as near as is desirable to their ports of outfit. So much for the times of peace.

But the entrance to the Caribbean Sea, which washes the shores of the southern isthmus, is commanded by English cannon. What would become of our access to our canal in time of war, located as it would be in a situation where its defense by us would be difficult, if not impossible? International wars may be expected to become more and more unfrequent, as commercial and industrial development establishes between the different peoples that community of material interests which is of itself the surest guaranty of peace; but provision must be made for a very different state of things; here again the extreme north of the Isthmus offers us special advantages. A canal terminating in the Gulf of Mexico would be very easily protected in time of war, and by making, in case of need, the Gulf a closed sea, our merchant marine would be secure from all attack, and our relations with the Pacific could be sustained without any interruption. This is a consideration which, in the eyes of our statesmen, ought to constitute an argument in favor of the more northerly locality.

I have thus very imperfectly sketched the great advantages, not to say the *necessity*, of withholding our assent as Americans from any project, however feasible it might appear, which looks to piercing the American Isthmus at Panama or Darien. I go further, and do not hesitate to declare my conviction that were there a strait now exisiting at Darien as

at Magellan, the necessities of American commerce would ultimately open a route through the Isthmus of Tehuantepec.

Look at the Peninsula of Florida—our government, not satisfied with the results of the survey under Gen. Bernard in 1829, have ordered a survey, under Gen. Gillmore, from Fernandina to Cedar Keys (150 miles). This, if opened for coasting trade, would pay in the reduced insurance growing out of the dangers of navigation through these seas in time of peace, and these dangers are even greater for sailing vessels further south, from the cyclones and hurricanes, which, as we approach the equator, are more frequent and violent than in higher latitudes, and add to the other impediments to safe navigation of the entrance of the Carribean Sea.

But so far from the strait being an existing fact, you are called upon to aid in making an artificial one, the obstacles to which the data in your possession tells you cannot be overcome save by an expenditure of life and money in its construction and maintenance out of all proportion to the comparatively limited amount of foreign commerce which would seek that channel. And the reliance for the support of the enterprise is looked for in the probability that American commerce would add its quota to its revenues, and its capital to its construction. In fact, without this latter it cannot be accomplished. Did no other attainable route offer, it is to be feared we might be seduced into lending our assistance to this, even to the ultimate injury to the *growth* of our commerce. We appeal to the patriotism of our people, and the statesmanship of our rulers, to prevent such a consummation. If foreign commerce can build and support such a movement, to their enterprise, and their hostility to American progress, it is questionable if we should look on without interference, but let us not ourselves commit hari-kari, to the manifest satisfaction of the enemies of our institutions.

It is a waste of words to discuss the bearings of the uncertainties as to the effect of deadly climate, tropical rains, absence of population, and materials for construction and supplies of all kinds, uncertainties as to geological features in their influence and cost, and character of material to be encountered, high and unheard of tunnels, aqueducts for the conveyance of angry rivers, earthquakes, infiltration, and undeveloped obstacles, to the successful construction and operation of rival projects —all hampered by the same difficulties, only in uncertain degree, and neither of which would our interests call upon us to accept at any price.

I allude to the various rival projects at Darien and Panama, the respective merits of which no longer interest us a practical problem, and we may dismiss them from consideration.

The conviction which is growing in the minds of intelligent men, as the facts open before them, is clearly that lifting locks are a *necessity* in any canal across the American Isthmus; if locks, it then becomes a question of *how many*, and at what cost, and in consequence, as the idea of a through cut fades away, we no longer consider millions of money a mere bagatelle, but look to the *cost* of a locked canal, and in consequence the Nicaraguan project has acquired an importance which a few years since it could scarcely have hoped to attain, and instead of fighting windmills at Panama, the field becomes really narrowed to a comparison of the respective merits of the Nicaragua and Tehuantepec ship canal projects with locks.

In a tabular comparison of distances we have shown the great preponderance which exists in favor of a transit by way of Tehuantepec rather than by Panama for American commerce, irrespective of engineering obstacles at either point, and for which I am indebted, as I have stated, to the researches of W. H. Stuckle, and which was undertaken by him before the route *via* Nicaragua had loomed up so prominently as now, and was scarcely regarded as a rival to the Tehuantepec. Time did not permit me a thorough reconstruction of those tables with sufficient accuracy to meet the new comparison now called for of Nicaragua with Tehuantepec, nor in view of an increased commercial tonnage, but a few notes will show the direction which this comparison would take.

The harbor of Greytown (San Juan) is in latitude 11° North, Panama being 7½°, while the mouth of Coatzacoalcos, on the Tehauntepec Isthmus in the Gulf of Mexico, is in latitude 18°. Panama, or rather Aspinwall, is 1 600 miles by steam from New Orleans, and Greytown, in Nicaragua, is 1 500 miles, while the Coatzacoalcos is 918 miles. The western port of the Nicaragua canal is 700 miles southeast of Tehuantepec, and nearly the same distance (640 miles) northwest of Panama; from New Orleans to Tehuantepec, on the Pacific coast, is 918 + 160 = 1 078 miles; from New Orleans to the same point *via* Nicaragua is (1 500 + 180 + 700) 2 380 miles, or more than twice as far; by way of Panama it is (1 600 + 1 340 + 50) 2 990 -say 3 090 miles.

It is true that as we extend to the ports on our eastern coast this difference becomes comparatively less, and when we consider foreign

ports it adds but a few miles to their voyage, whether Nicarauga or Panama be the point of transit. The former route would lessen their distance to our Pacific coast, and increase it for the western coast of South America. But the margin of difference is small for foreign commerce by the adoption of either of the more northerly routes than Panama, and the difference to foreign commerce between adopting Nicaragua or Tehuantepec, on the score of distance solely, is insignificant, while to us in competition with foreign commerce it may be vital, as is shown by the tables of distances already noted.

Thus we see that *all* the advantages exhibited in these tables of distances, and the arguments based upon them in favor of the Tehuantepec over the Panama route, differ in *degree* only, and not in kind, when applied to the Nicaragua transit, which latter, in its inception and nature is *foreign*, debouching into the Carribean Sea, the command of which will be beyond our control, instead of into the Gulf of Mexico, which, in common with Mexico, we may call our own sea.

We come now to local considerations of the rival routes of Nicaragua and Tehuantepec. As the highest order of tactical skill will not compensate for defective strategy in influencing the results of a military campaign, so the ablest efforts of constructive engineering, and even a certain amount of local facility, will not compensate for errors in the selection of the locality of the work, if of national importance; or, in other words, the advantages to be anticipated from a comparatively cheap canal will be lost to commerce if it be built in the wrong place.

It will be expected that some comparison be instituted between the commercial values of the two routes by way of Tehuantepec and by way of Nicaragua, although, as we have seen, we consider the question to be entirely independent of the relative cost of the two routes ; but if either of them be hampered by natural obstacles, which cannot be overcome save by anticipating improvements yet to be effected in the mechanic arts, and so far problematical in their results, these obstacles should be fairly stated, and due weight given to them, in view of the great interests at stake in the selection of the proper inter-oceanic water-way, which shall best subserve the interests of American commerce.

From such data as we now possess, it would appear that the difference in the first cost of these two routes is not sufficiently great to make that the controlling element in the comparison of these respective routes, even supposing that they were otherwise on an equality ; but as Rear-

Admiral Ammen has, in his letter of date January 26, 1880, stated that there were but two routes worth looking at, viz., Panama and Nicaragua, and deprecates the agitation of the claims of the Tehuantepec route at this time, as the latter route, he declares "is simply impossible of execution by reason of physical ob tacles," and that "the object could not be to hope to make a canal there, but simply to prevent its execution elsewhere," I feel constrained to refer to the respective estimates of the two routes, and show Admiral Ammen's method of estimating the cost of ship canals.

To exhibit the overwhelming difficulties in the way of the construction of the Tehuantepec canal, Admiral Ammen makes an estimate of its cost by taking the items of the Nicaragua canal estimate of Mr. Menocal and applying them to the Tehuantepec route as he understands it, and by such process reaches the sum of $130 000 000 as the cost of the latter canal, and then says that, when on a commission appointed by the President of the United States, in 1872, to examine and report upon the cost of the Nicaragua Ship Canal, he determined that the estimate of Mr. Menocal for that work submitted to him was too low, and in his opinion should be *doubled*, thus increasing it from $52 000 000 to $100-000 000, "therefore he should double the result of his estimate, as shown above, for the Tehuantepec Canal," and adds, "that there is greater reason for thus doubling it than existed in the case of the Nicaragua Canal estimates," and in consequence he declares that the Tehuantepec Ship Canal will cost $260 000 000 ! and with an inadequate water supply in the dry season.

As to the sufficiency of water, we have ample evidence, from the report of Commander Shufeldt, and with reference to the detail of Mr. Menocal's estimate of work required at Nicaragua, whether properly applicable to the Tehuantepec line or not, we cannot but think, from the obvious care used in its preparation, that it should be accepted as the standard for the location for which it was designed ; but it does not profess to give more than the cash value of the work to be done, without taking into consideration the financial difficulties attending the raising the requisite funds. When the cost of the Suez Canal had reached $70 000 000 (fifteen millions of this is embraced in the item of "financial management," interest on stock and bonds, etc.), we may fairly suppose, that taking Mr. Menocal's estimate of $65 722 000 (which does not embrace any interest account) an additional item of $15 000 000 at

least on this account might properly be added to cover the entire cost of the work. Had Admiral Ammen confined himself to this, or some such modification of Mr. Menocal's estimate, his statement would have been entitled to attention which it cannot now command.

We propose to accept Mr. Menocal's estimate of $65 722 000 as covering the cost of construction, irrespective of the additional amount which financial considerations might render necessary, and which we may suppose would be encountered proportionally by any enterprise requiring promptly such large sums of money.

Mr. Menocal's estimate is:

181¼ miles of canal, slack water and lake	$47 417 000
Harbor of Brito	2 338 000
Harbor of Greytown	2 823 000
	$52 578 000
Contingencies, 25 per cent	13 144 000
	$65 722 000

One word as to the harbors, before proceeding to the Tehuantepec estimates.

Greytown harbor is liable to being closed by shifting sand-bars. Did the San Juan River, with its full volume, reach the sea at Greytown, its current could be so controlled as to preserve a free channel against the littoral current of the coast, but $\frac{2}{3}\frac{9}{0}$ of its volume is drawn off into the Colorado, or rather forms the Colorado, some fifteen miles above Greytown, which, running through the territories of Costa Rica, could not be diverted into the San Juan River unless by treaty stipulations, which it would be difficult, if not impossible, to obtain—so that maintaining a ship channel harbor at Greytown would be attended with very great expense.

As to Brito, on the Pacific, I know nothing but that it is now a mere open roadstead, and Mr. Menocal himself says: "At Brito, a breakwater, a pier, and dredging will be required to build a harbor large enough to secure a smooth entrance to the canal, and accommodate a *number* of vessels. *With the lake, only* 16 *miles* from the sea by the canal, possessing all the advantages of an excellent internal harbor, capable of accommodating all the fleets of the world, the harbor of Brito *need not be large.*"

This indicates pretty clearly what it now is, and what it is proposed to make it. Neither of these harbors can be improved but by an enormous expenditure and a large annual outlay for maintenance.

As less known to you, I must explain more fully the location of the Tehuantepec Isthmus, which is the narrow land between Southern Mexico and her easterly province of Yucatan, and from the shores of the Gulf of Mexico to the Pacific Ocean is 135 miles directly north and south.

The range of the Cordilleras here, as elsewhere in Central America, bears nearer the Pacific coast, leaving a plain of some 20 or 30 miles in width from the foot of the hills to the ocean, and on the Gulf side a much more gradual slope of twice that distance. The mountain peaks of from 4 to 7 thousand feet in height, fall away on either side, leaving a comparatively low pass through the high land, with a tolerably flat summit or plain, which is occupied from the summits on the east and west, each way, by streams of considerable magnitude, feeding rivers which empty into the Gulf on one side and into the Pacific on the other. On the Pacific side two or three large lagoons set up from the ocean, grouped together and in communication with each other; their extreme length some 30 miles, and breadth 15 miles. Into these lagoons several of the large rivers empty their waters, having a communication with the Pacific by an opening called the Bocobaca. These lagoons are shallow in many directions, but the bottom of silt and sand is easily excavated, and the railway company, to be spoken of presently, I am informed, design to make use of these lagoons for harbor purposes, with deep water and protected opening into the ocean.

On the Atlantic slope, the river Coatzacoalcos, with large affluents, empties into the Gulf of Mexico. This river has a bar at its mouth with 18 feet of water at low tide, very permanent, neither having shifted nor lessened in depth since the time of Cortez, and when a passage is once opened through, can be kept open at a very trifling cost. The river is of good width, one-half to one-quarter of a mile, with gentle current, and passing the bar a depth of 5 or 6 fathoms is had, and 30 feet of water can be carried for 20 miles and 26 feet of water for a distance of 35 miles from the bar; soft bottom. From this point the Island of Tacamichapa, formed by two branches of the Coatzacoalcos uniting, to the mouth of the river Malatengo, a slack-water navigation, with locks and dams, can be had, according to M. Moro's views—mostly

clay and gravel excavation. From this point, the mouth of the Malatengo, 28 miles of canal will reach the summit plains of Tarifa; at a level of about 650 feet, where a feeder of some 26 miles in length, from the Sierra at the east, will supply water to the extent of 2 000 cubic feet per second at the dryest season. From thence, the canal will descend for 23 miles to the lagoons on the Pacific, which will constitute the termination on the western coast. The 650 feet of elevation will require, at 12 and 10 feet lifts, 55 locks from the summit on each side; perhaps a few more may become necessary, as further examination may determine.

Every material needed in construction is found on the Isthmus in profusion, with a climate of uncommon salubrity, and a prolific soil. The forests abound in inexhaustable quantities of the most valuable timber—timber which resists most wonderfully the ravages of time and the elements, and resists the attacks of insects beyond anything grown in these northern latitudes, as existing structures of almost fabulous duration attest. Amongst others the *quo pague* has a reputation in this respect which has led to its extensive use elsewhere for railroad ties—and this brings me to a point made in the report of the Commission of Engineers, referred to as having visited the European works in 1871, in the interest of the projection of the ship canal here, under the Le Sere grant, and recommended the construction of the Tehuantepec Ship Canal. They say, in quoting from a foreign writer on this subject, M. de Gamond, "that it would be an error to think we can in this enterprise copy works executed in Europe under the formal rules of construction there adhered to. It is necessary, above all things, for the accomplishment of such an enterprise, to lay under contribution the immense local resources of nature, and to utilize in the employment of these resources that which is most applicable in the distinctive genius of every nation." The immense forests of the most valuable and durable timber, which lie along the route, should provide the material for locks and aqueducts, by which the expense of these otherwise most costly structures will be reduced to a fraction of that which masonry would require. We need not refer to the use of timber in the United States for preliminary works. To adopt its use at Tehuantepec is but to adopt the principle of M. Gamond, and to apply the distinctive genius of American construction to an American work, and at the same time utilize the immense constructive resources offered us in the forests of Tehuantepec.

The present transition state of ocean navigation, in which a substitution of steam for sails, and of steam vessels of enormous length for existing models, furnishes an independent and an adequate motive for the use of timber combined with stone for locks. While it would be imprudent to hamper navigation by "monumental" constructions of dimensions which might prove inadequate in the future, it would certainly be premature to build, in masonry, locks of the enormous dimensions that some ship-builders anticipate our steamships are destined to attain.

I would propose, that until experience had pointed out more clearly the requisite dimensions for ship canal locks, that they be built of the durable timber of the Isthmus, which will prove more serviceable than would locks entirely of masonry.

An American company with a grant for a railroad from the Government of Mexico, is now engaged in constructing a railroad across this Isthmus. The line of road does not encroach upon the ground possible for a canal, while it is sufficiently near to make the transportation of laborers and materials a large element of economy in its cost and management. This railway company, under the terms of their grant from the Government, are required to construct the harbors at either termini, on the Pacific and on the Gulf, with a depth of 28 feet of water, suitable to the requirements of modern commerce, which it will be to their interest to accomplish to the extent of exceeding in convenience any harbors now existing on either coast. On the Gulf, nothing more is needed to make a harbor in capacity and safety equal to any in the world than to open a proper channel for a few hundred yards (800) through a permanent bar, and on the Pacific, the same facility is anticipated in utilizing the upper lagoon.

Mr. Wm. J. McAlpine, is Consulting Engineer of this company, and this will be a guarantee that what they undertake in hydraulic works will be thoroughly accomplished. Their Chief Engineer, Mr. Van Brocklin, is also a member of this Society. Both of these gentlemen are now there, and as the work progresses, data for the proper determination of the canal location will be developed, and it could not be in better hands.

The present company have not a concession from the Government for the construction of a canal, but only the railway, which, when constructed, will insure the carrying out of the ship canal project, in the most economical manner possible.

We are not in possession of the data desirable from a location survey and profile for a canal on this Isthmus. M. Moro, with full means in his possession for the prosecution of his enquiries, spent nine months on the Isthmus, having in view solely the construction of a ship canal, and could see no reason whatever, either from climate, or facilities for supplies, both of material and labor, why the work should cost more than similar work in Europe. To be sure (this was in 1842) the dimensions of ships had not reached the point to which they have since progressed, and he assumed for a ship canal, the model of the Caledonian canal in Scotland, width of top water 120 feet, bottom 50 feet, and depth 20 feet—a very respectable canal even now—but his locks were restricted to the commerce of the day, as seen in that canal—length 180 feet, and breadth 40 feet, with 8 feet lifts. On this basis, with a thorough knowledge of all the difficulties to be encountered, including expensive feeders with tunnels, he estimated the cost of the entire work at $17 000 000, building materials, stone, lime, &c., abounding in the locality.

Without intending any disparagement to the labors of Prof. Fuertes, whose report in connection with this work exhibits great ability, I quote from M. Moro the level of the summit pass at Tarifa as 200 metres (656′). The lowest level given by Mr. Fuertes is 707 feet. The latter engineer gives a profile of the feeder some 27 miles in length, on which there are several tunnels, but this is not intended for navigation. And to do away with the prejudice which a paper read before the Geographical Society would give rise to, I beg leave to state that no tunnel for the navigable canal is contemplated on the Tehuantepec Isthmus. The precise depth of the summit cut I am unable to state, but it need not be greater than many railroad cuts in this country, and comparatively for a limited distance, and while it is probable that some rock may be encountered, appearances indicate that most of the excavations will be in less formidable material. From the best data in my possession, I beg leave to propose the following, as in my judgment ample for the construction of this canal, taking the same cross dimensions of canal and locks as were assumed by Mr. Menocal at Nicaragua, viz: canal $\frac{150}{84}$—22 feet depth; locks, 400′×60′; 10′ and 12′ lift; but the latter, combined locks of timber and stone, and no harbors estimated for, as the existing grant to the railway company provides for these:

From the Gulf of Mexico to Island of Tacamichapa, on Coatzacoalcos River	40 miles.
Canal to Malatengo River	54 "
Canal up Chichihua River to Tarifa	25 "
From Tarifa to Upper Lagoon	26 "
By way of railway company's works through the lagoon to Pacific Ocean	15 "
Total distance	160 miles.
or to construct by the canal company	40 miles river, 105 " canal.
Total	145 miles.

Locks, 13 of 10½ feet lift each, and 97 of 12 feet lift—total, 110 locks, 650 feet:

110 locks at $100 000	$11 000 000
105 miles canal at $300 000	31 500 000
27 miles feeder, $200 000	5 400 000
Contingencies, 20 per cent	9 600 000
	$57 500 000

We believe that the Coatzacoalcos River admits largely of slack-water improvement, if not to the junction of the Malatengo, certainly for many miles above the Island of Tacamichapa, and that in that event the above estimates would admit of a large reduction, but as we are putting ourselves on record in this matter, we prefer to be on the safe side. The principle of hydraulic excavation is peculiarly applicable to this work, by reason of the character of the streams emptying into the main valley and the material to be excavated and the opportunity for waste-weirs and side cuts in the improvement of the Coatzacoalcos (not being inclosed in a narrow ravine), all point to an economical result.

Nor is a lock of these dimensions, built of timber, an experiment. A graving dock has been in successful operation for several years in Brooklyn, at the Erie Basin, built of Southern pine, 500 feet in length, 60 feet in breadth, and with 22 feet water, and is considered as preferable to a stone dock in every respect, and at a cost which justifies my estimate above of $100 000 per lock.

If a proper system of fenders and posts is provided, and a sufficient number of filling culverts properly spaced in the locks, particularly if the latter be of timber, I can see no reason whatever to apprehend any liability to accident. With ordinary care a ship may pass such a lock without marring the paint of her bends—and within twenty minutes of time.

There remains to compare the respective times of transit:

Tehuantepec Isthmus—

40 miles of open river, at 10 miles per hour.....	4 hours.
105 miles canal, at 4 miles per hour.....	26 "
110 locks at 20 minutes.....	37 "
	67 hours.
Estimate of Mr. Menocal for Nicaragua.....	38½ "
Difference of time in favor of Nicaragua.....	28½ "

Whatever may be the advantage in point of time of a transit at Panama over that at Nicaragua, as we are dealing with the latter entirely in this comparison, we have to state that the passage of the Tehuantepec Canal will require one day more than the canal at Nicaragua, or, at the outside, two days. As regards the objections to locks—whatever route be adopted, even the through cut, so called, if it can be built, will require a tide-lock, at least, on the Pacific. In admitting that mean tide on either side would be at the same time the rise on one side of 20 odd feet, and on the other of 1½ feet, would require a tide-lock for adjustment of current. The fact that the Red Sea level was *traditionally* some 30 feet above the Mediteranean, and results demonstrated in a canal of 90 miles in length, connecting the two, that the difference was really inappreciable, has no bearing whatever upon this question.

The route which, as we have seen, while giving all proper facility to European commerce through American water-ways, still from its geographical position gives a proper preponderance to our domestic commerce, requires the use of lift-locks. Shall 24 or 48 hours additional time for its passage, and the bugbear of the danger of such transit, which differs but in degree, and not in kind, from the most favorable route which European interests can point out, deter American enterprise from carrying out what the interests of her growing domestic commerce calls for, and leave her to gather such crumbs as older nations have determined shall be her share?

Public opinion is beginning to express itself, in a manner not to be mistaken, adverse to any foreign occupancy among the small States of Central America, where a question of the infringement of the rights of such occupants by the local government could so easily be made the pretext for the interference of a foreign power, ostensibly for the protection of the rights of its own citizens, but virtually to deprive this Government of the control of her own domestic trade. This feeling has been aroused by the late movements of a French company at Panama. But, indeed, either at Panama or at Nicaragua, if a ship canal should be built under circumstances of control nominally favorable to this country, and in accord with the spirit of the Monroe doctrine, as we construe it, yet its location, although endorsed by high officials, would, as we have seen, be so much more favorable to foreign than to American commerce that the legitimate growth of the latter would be completely crippled; and to prevent such a consummation we must go still further, and refuse countenance or support, in any way, to the construction of a ship canal located at any point south of the Peninsula of Yucatan; or, in other words, south of the Isthmus of Tehuantepec. And the importance of enlightening our people as to the national bearing of this question of the location of a ahip canal cannot be overestimated. It is no longer *who* shall build it, nor *how*, but *where* it shall be built, that interests us as American citizens.

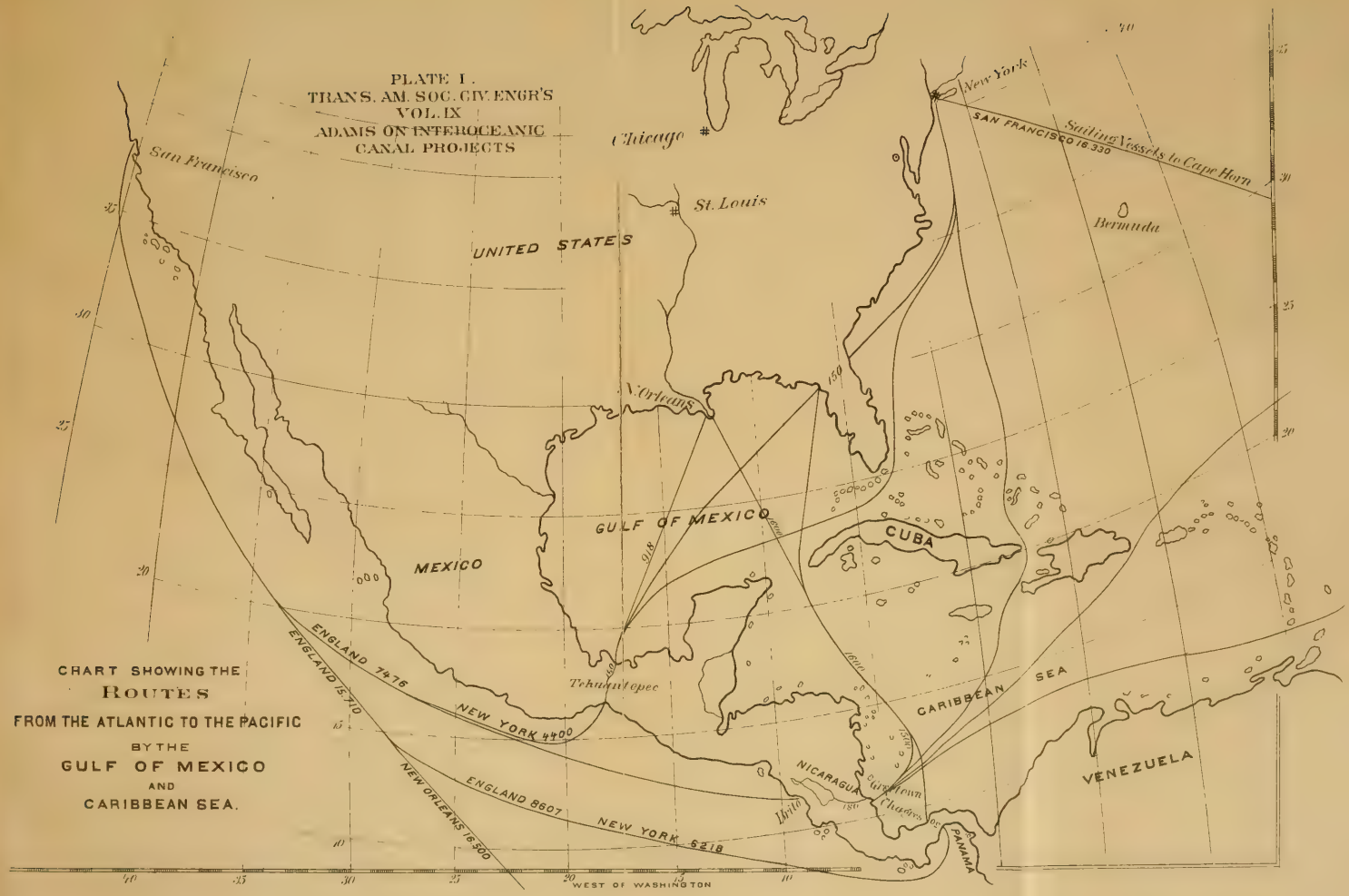
PLATE I.
TRANS. AM. SOC. CIV. ENGR'S
VOL. IX
ADAMS ON INTEROCEANIC
CANAL PROJECTS
CHART SHOWING THE
ROUTES
FROM THE ATLANTIC TO THE PACIFIC
BY THE
GULF OF MEXICO
AND
CARIBBEAN SEA.
San Francisco
Chicago
St. Louis
New York
UNITED STATES
MEXICO
GULF OF MEXICO
CUBA
CARIBBEAN SEA
VENEZUELA
NICARAGUA
PANAMA
Bermuda
Tehuantepec
Chagres
Greytown
SAN FRANCISCO 16,330
Sailing Vessels to Cape Horn
ENGLAND 7476
ENGLAND 15,570
NEW YORK 4400
NEW ORLEANS 16,900
ENGLAND 8607
NEW YORK 5218
WEST OF WASHINGTON

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

(Vol. IX.—March, 1880.)

INTER-OCEANIC CANAL PROJECTS.*

By FERDINAND DE LESSEPS, J. DIRKS and V. DAUZATS.

M. Ferdinand de Lesseps, having accepted the invitation to attend a meeting of the Society, and intimated his preference to be first introduced to the American public by the Civil Engineers, a special meeting of the Society was held in New York, on the evening of February 26th, 1880, at the theatre of the Union League Club. The attendance was large, comprising many members of the Society, leading citizens and invited guests, many of the latter being ladies.

Introduction by O. CHANUTE.

Vice-President O. Chanute was in the chair, and after calling the meeting to order, said :

This is a special adjourned meeting of the American Society of Civil Engineers, held for the purpose of welcoming to the United States the distinguished Engineers who have just arrived from Central America, and of hearing what they wish to say concerning the American Inter-Oceanic Canal. We shall first be addressed by M. de Lesseps. As, much to his regret, he does not speak English, his communication will be made in French, and, at his request, a synopsis of each portion of it will be made in English by Mr. N. Appleton. M. de

*Inter-Oceanic Canal Projects, by A. G. Menocal, Vol. VII, p. 311 (November, 1879). Discussions on the subject, Vol. IX, p. 1 (January, 1880), and Vol. IX, p. 47 (February, 1880).

Lesseps will also answer any questions which may be asked. After he has terminated, we shall have an account of the works proposed, by Mr. J. Dirks, Chief Engineer of the canal from Amsterdam to the sea.

The American Society of Civil Engineers has heretofore endeavored to contribute its share toward the understanding of the subject of the Inter-Oceanic Canal, by gathering information concerning the various routes, the plans proposed for the canal, their probable cost, and the commercial bearings of the project.

This it has done, not with a view to revising the plans of what is, after all, a private enterprise; nor to pass judgment upon them, for the Society commits itself, as a body, to no views, and neither for nor against any project, but rather to collect the data required, that its individual members might form an intelligent opinion concerning the merits and probable results of an important undertaking, in which the American public is to be invited to take a share.

Beginning in November last, with the reading of a paper upon "Inter-Oceanic Canal Projects," by Mr. Menocal, member of the Society, and one of the delegates to the Paris Congress, the discussion has been participated in by many prominent members of the Society, as well as by several gentlemen who promote particular routes, and we have been fully informed concerning the San Blas, the Nicaragua, and the Tehuantepec routes.

But little has yet been said in these discussions concerning the Panama route; it being generally felt, that pending the proposed revision of the location and of the plans for the canal, by the very able engineers who had the matter in charge, it was desirable, before any opinions were expressed, to await the announcement of the results.

We are now able to learn these results, as well as the facts and plans upon which they are based, in the most direct, certain, and satisfactory manner: for we have among us to-night, as a guest, the chief manager and promoter of the enterprise; a gentleman of world-wide fame, as the builder of the Suez Canal, who, having already accomplished labors which to other men would be the work of a lifetime, having connected in the face of the most strenuous difficulties, two great seas across the trackless sand of the desert, now proposes to perform the still greater feat of cleaving the American Isthmus asunder, to connect the two great oceans of the world. Gentlemen, I have the honor to introduce to you M. Ferdinand de Lesseps.

Discussion by M. Ferdinand de Lesseps.

Mr. President and Members of the American Society of Civil Engineers, Ladies and Gentlemen: I am very happy to be here this evening, not only because it gives me an opportunity to set forth my views on the great project which I have so much at heart, and which I think when completed will be so great a blessing to mankind, but also at finding myself immediately upon my arrival in America, the much honored guest of this Society of Civil Engineers, before which, above all others, I consider it proper that I should first address myself. I am not an engineer by education, having been for so many years in the profession of a diplomatist, yet I am happy to be received as an engineer, and I am happy on that account as well as for the personal honors which have been paid me and the many opportunities afforded me for seeing in the short time I have already spent on shore what were to me most interesting and instructive illustrations of American engineering, skill and science.

I desire to begin at the beginning. In 1870, soon after the completion of the Suez Canal, and after that work had begun to be put into regular use, I began to think seriously upon the question of an interoceanic canal across the narrow land separating the two oceans in the Western Hemisphere. The first difficulty was the supposed difference in the levels of the two seas. An impression that there was such a difference had gone out and in many quarters was seriously believed, though for what reason I could not find out. Upon a careful examination it was discovered that this difference of sea-level was a myth, and that the only basis of the myth was the ebb and flow of the tide, which differed on the two sides of the Isthmus, but which would make no difficulty in the construction of a sea-level canal—for that from the first was the sort of a canal on which I had set my heart, and which I will build or abandon the project. I will not take up the various steps through which we passed in the consideration of this problem, for I can assure you that there were much study and many investigations during the years intervening between my first determination on the subject and the present time.

I determined not to occupy myself with political opinions, but from the moment I began the enterprise to devote myself to the practical part of the undertaking. I looked at the subject from a commercial view.

I am convinced and persuaded that the enterprise will be not only for the great advantage of commerce, affording an easy route to the Asian continent or India or Japan, but will produce results which will

develop the shipping interests of the United States to the place they occupied twenty-five years ago.

I had the honor of the acquaintance of Senator Sumner when he visited France, and he gave me many valuable figures on the state of American shipping at that time. He stated that the tonnage of American commerce at that time was about 5 500 000 tons. England at the same period had about 5 000 000 tons. All the commerce of the earth could have been divided into three sections, America owning one, England another, and all other nations together having an amount about equal to that possessed by each of these. Since that time America has fallen away as regards maritime commerce, and especially since the opening of the Suez Canal. Its commerce is very low, much more so than it should be for a people so great and powerful as the Americans. But I reflected that this was not to remain so; it cannot remain so with the Panama Canal open to encourage American shipping, as it certainly will do.

The Suez Canal has had the effect of changing the commerce of the whole world, and improved its shipping to an extent altogether unanticipated. It has caused the building of large steam vessels, which have supplanted the sailing ships. You will see that a similar metamorphosis will follow the opening of a Panama Canal. American shipping has fallen off since the war, and the mercantile marine, I am informed, is now in a deplorable condition. The opening of such a canal would give a fresh impetus to the building of American shipping and assist you in regaining the position that you have lost. To-day I say to the American people, prepare yourselves in six or seven years to see your commerce extended from the North Pole to the South. When you shall have comprehended the importance of the canal you will see that your commerce will be benefited according to your large population, and that no other country will have pre-eminence over you when the canal is opened. I work not for selfish motives, but for the interests of humanity. Should you not, therefore, concur in the project as other countries have done?

I will compare the Suez Canal with that proposed at Panama, and show, as I hope, that the one across the Isthmus would be an easier matter than that joining the Red Sea and the Mediterranean. In the first place, there was no precedent for the Suez Canal in modern times. The ground had been a battlefield of nations since the commencement of historic times. In the time of the Pharaohs, there were fresh water canals in Egypt, in the construction of which the natural watercourses were often utilized.

The first canal proposed for crossing the Isthmus of Suez was in the time of Philip II. He at first acquiesced in the idea, but being a very jealous monarch, and afraid that other nations might profit by the canal, he afterwards insisted that the project should be abandoned. An edict was issued declaring all men impious who should propose such a canal. Even if they spoke about it they were to be put to death. This was his order, and as they knew he had the power to carry it out, the subject of the canal was quickly dropped. I hope the example of Philip II. will not be followed in America. It would be very inconvenient for some of us to have such an edict in force.

Since the time of Columbus there have not been wanting those who thought that the American Isthmus could be traversed. It was first thought feasible by using the natural ports, lakes and rivers. The regular study of the question of the inter-oceanic canal began in 1875. There was then at Paris a universal geographical congress, and there I talked with Professor Nourse, from your Government offices in Washington, and I discovered how much interest was felt in the canal in America. I was charged to preside over the inter-oceanic section, and I obtained from Washington all the plans of proposed routes. Of all countries the most concerned was America. Some said that America did not want the canal, but I replied, "You deceive yourselves. America wants to develop commerce in the entire world." To prove that America wanted the canal, perhaps I exaggerated a little, but I said that she had spent already about $1,000,000 in exploration and in the attempts to find out how to start right in this great work. I said at the Conference that America having built a line of railroad across the Isthmus, it was a good argument in favor of crossing it at that point. The American engineers chose this route thirty years ago, and built their railroad there.

A new congress was proposed, to which that special question of the canal was to be referred. I wrote a number of letters to leading engineers in Europe and America, inviting them to come to Paris to discuss this scheme. Every one came at his own expense, and the first engineers of Europe were there. Over one hundred persons were present, the élite of the entire engineering world. We were divided up into sections, one on engineering, one on navigation, one on statistics, one on the movement of commerce, and one on finances. Each committee commenced its work without wasting any time. I said we should go to work

a l'Americaine. "How is that?" they asked. "Quickly," I said. And after what I saw yesterday, I can say that I never before knew fully what it was to speak of anything being *a l'Americaine.* Now I know what it is when I see your bold street elevated road and your magnificent bridge and your other works of freedom in science.

At it we went for fifteen days, night and day. All our deliberations were afterward printed. I remember that in connection with the Congress something was said to the effect that the American delegation was not treated with due consideration. This was an erroneous idea. Admiral Ammen was made First Vice-President. I do not think any discussion was started that the Americans were not in courtesy first called upon to speak upon it, and when it came to the final vote, every man could vote as he pleased, and also give in writing his reasons for the vote. There was not only no disfavor shown the Americans, but I was even charged with showing partiality to them, and this charge will be found in the printed report of the proceedings. At the final vote, 78 voted for the Panama route and 8 against, 12 declining to vote. I did not expect until the last day to occupy the place I now do at the head of this gigantic work, but when I heard the exclamations of the Congress, and saw there before me, as I see it now, the face of my wife, I felt that I ought to put myself at the head of this work, and the completion of the circumnavigation of the globe.

I thought, moreover, I had not the right, after having gone so far, to refuse to see the work through. It would have been cowardice not to continue, so I advanced in spite of the opinion of Mme. de Lesseps. It has brought now the pleasure of a visit to America, and the enjoyment of the hospitalities which are now showering upon me, and which I should not otherwise have enjoyed.

The first thing after this was to get the concessions from the Compagnie Civile, which that body had secured from the State of Colombia. My plan was to offer the company $1 000 000 in cash when the subscription for our undertaking should be taken up, and $1 000 000 in the stock of the new company. This new company has not succeeded, partly on account of the opposition of the press, and the press is a great power and deserves to direct public opinion when it is managed by honest men. The subscription was not a success, and I paid back the money to all who had subscribed. Thereupon some of my friends came together, and placed $400,000 in my hands to enable me to verify the surveys, and

to pay the deposit required by the Colombian Goverment. I could not have done this with my own means. I am not ashamed to say that I have no fortune. I have passed twenty years in diplomacy and thirty years in engineering, but I did not profit by any of the enterprises which I began. It is not my trade ; I make it a principle not to gain anything from others. I have only the shares which I pay for myself. Those who invested their money in the enterprise have taken a great risk and have a fair right to the fruits of success. Now my work has commenced of executing the enterprise. It is a work of the entire world, not only for other nations, but especially for America.

Let us talk of the technical part. Determined to make a verification of former surveys upon which I had based my scheme, I repaired to Panama with a party of ten well-known engineers. The expedition to the country has been safely accomplished, notwithstanding the dangers forboded to us. Much has been said against the climate of Panama ; but we did not suffer from it at all. The climate of Suez is infinitely worse. The heat at Panama is from 23 to 33 Centigrade; at Suez 30 to 35°. We all came back in safety. The country was not dangerous at all, and was much more favorable to such an undertaking than that surrounding the Suez Canal, which I will now tell you of. The most celebrated engineers of France and England did not expect such a great success. I was treated as a fool because I simply desired to cut away the earth, whereas they had expected I would make a canal with the assistance of the Nile. I took engineers there and we occupied the territory. There was no water near, no houses, and it was nothing but a great plain of sand, containing nothing that could be of use to us. We used camels, and our laborers were divided in companies, some going in search of water while the others worked. There are no rains at Suez; it never rains there. The difficulties were almost insurmountable. There were battles with workmen, water had to be carried sixty leagues, we had fierce storms to encounter, and for the first two or three years we scarcely got a foothold. The sand did not frighten me as it did the public. It did not take much trouble to remove it, of course, and most of it was done by hand, before we had machines. But the taking out of clay was a more serious undertaking ; in some respects it was more difficult to deal with than stone, because it could not be blasted or removed in blocks. Suez was far worse than Panama can be. We remember how we were told most solemnly that Suez could not be built, but

we went, I shall say again, *a l' Americaine*, and did it, and now we propose to do it again. I have shown you the difficulties at Suez; at Panama there are no such difficulties.

Now referring to a model in relief, of the proposed line of the Panama Canal, I will briefly sketch the route for the canal: It begins on the Atlantic side, at Colon (Aspinwall), and joins the valley of the River Chagres, a little south of the bay of Limon. The River Chagres however, does not empty into the Bay of Limon, but into the sea at the old town of Chagres. The canal follows the valley of this river to a point near Matachin, where the river has a sharp turn towards the northeast, and runs between two mountains. Here the canal leaves this valley, and it is proposed to construct a dam between these two mountains to provide for the storage of the flood waters of the river. This dam will be forty meters in height, and will retain about one thousand millions cubic metres of water. There are at least three dams in the world, which are of equal magnitude with this, and which have stood for many years; one in Spain is higher, and has endured three centuries.

The canal, leaving the valley of the Chagres, cuts through the mountains at Culebra, where the extreme depth of cutting will be about 270 feet, almost exactly the same as that of the towers of your great Brooklyn bridge, which you have just kindly shown us. Thence the canal will follow the valley of the Rio Grande to the Pacific, which it enters near the City of Panama.

Another advantage possessed by the Isthmus of Panama over that of Suez is its fertility, being a perfect paradise; there is no botanical garden in the world which could surpass it in beauty. The stations on the American railroad are surrounded by villages, and there is plenty of game in the mountains. I leave to the engineers with me the explanation of the details of the proposed plan, who will report as to the country which they have passed through, and after they have finished I will be at the disposal of the public to respond to all questions which any one may choose to ask.

Now, I beg to present this model to the Society of Civil Engineers, and to thank them for this opportunity of addressing you.

Discussion by J. Dirks.

In the first place I beg to call your attention to the fact that neither the English nor the French is my native language. For this reason I invoke your kindness in overlooking any mistake as regards pronunciation; also grammatical errors. M. de Lesseps, the great mind who pulled down the Suez barrier, and therefore deserved, as well as earned, the thanks of mankind in general—came to America with the object of removing a second barrier, in joining together both oceans by a great ship canal through the American Isthmus. Allow me, ladies and gentlemen, to explain, in a few words, why M. de Lesseps deemed it convenient to invite me to join, not alone the Paris Congress of May last, but the scientific and technical survey of the canal line between Colon (Aspinwall) and Panama, which took place during the last few weeks. I have the advantage of being the engineer of the ship canal going from Amsterdam to the sea, which canal is fully described by your esteemed countryman, General Barnard, and was visited as well by himself as by other engineers of this great country, among them Captain Eads, the renowned builder of the St. Louis Bridge and of the wonderful works at the mouth of the Mississippi. When the general plan of the Amsterdam Canal was proposed, about 1860, only very few engineers believed in its feasibility, and the majority of scientific men were of opinion that a sea harbor in the shifting sands of the broad and shallow beach at the North Sea, as well as the dredging of a canal in the very soft mud of the lake through which it ran, were to be considered as quite impossible. Belonging to the small minority who were convinced that the Amsterdam Canal could be made and would fully answer the purpose, I was charged with the execution of the whole, in conjunction with Sir John Hawkshaw, from London, who acted as consulting engineer.

It is a great satisfaction to me that the Amsterdam Canal has been constructed; that the dark forebodings of a large majority never were realized; that the canal, at a cost of about $16 000 000, is a complete success, and that the largest vessels, even to a draught of twenty-four feet, easily enter and leave the new North Sea Harbor and get to Amsterdam within four or five hours. If not for the results of this proportionally smaller, but nevertheless very important scheme, M. de Lesseps would very likely never have known even my name. I have to thank him here for his kind opinion regarding the little experience in canal matters that I may have got, and I beg to state at the same time, as recorded above,

that I was not alone in my quality of acting chief engineer, but that the great mind of my friend, John Hawkshaw, was there also, in order to avoid or to put aside many difficulties of planning and construction. As regards the technical possibility of a level ship canal between both oceans at Panama, I am happy to say again what I told a few days ago to some very competent men, namely, that I would like to write down my very favorable opinion in very large characters and put at stake my reputation as an engineer that the difficulties of this enormous work will be not greater—perhaps even less important—than those of the Suez Canal and of so many other great works completed with full success in America and in Europe. I want to state that the making of a deep cutting is just as possible at Panama as in the United States; that the blowing up of rocks may be done there even with greater facility than at Hell Gate, near this city, and, finally, that the only serious technical question to be solved is that of the floods of the River Chagres, through the alluvial and present bed of which a great part of the ship canal will have to be led. But even that difficulty can be surmounted. The result of the studies of Colonel Totten and Mr. Dauzats, who went into the question with the utmost care, was set forth in the international report recently published, and known, as I presume, to the members of this scientific body. I may therefore confine myself to the renewed expression of my heartfelt thanks to the chairman and the members of the American Society of Civil Engineers, as well as to many other citizens of this great city. They show their regards and kind sympathy not only for the engineer but also for the Dutchman. They talk feelingly about the old ties between my country and the United States. The same old blood is running through the veins of many on both sides of the Atlantic, and what happened in past times may lead toward what may occur in the future, the relations between both peoples and the other nations will be progressing forever, and each barrier pulled down on the broad way of commerce and industry will largely contribute toward such a blessed prospect.

O. Chanute.—M. de Lesseps is now prepared to answer questions, and I will begin by asking him, what are the estimates of the probable cost of the undertaking, and the probable returns ?

M. De Lesseps.—One hundred and sixty-eight millions of dollars. Of this $20 000 000 are for the large dam to keep the waters of the River Chagres in. It would not be necessary to have the work entirely com-

pleted before vessels could be sent through. I am satisfied, too, that the final operations will show a considerable reduction. This is the reason that induces me to fix the capital at 600 000 000f. or $120 000 000. But should my hopes in this direction not be fulfilled, the difference necessary to make up the estimate can be supplied by bonds or otherwise.

According to the returns of the Congress at Paris, it was calculated by M. Levasseur, the Chairman of the Committee on Statistics, that 6 000 000 tons would pass through the canal in a year, and that within ten years they would rise to 7 250 000. At Suez the tariff was 10 francs or $2 per ton, but at Panama it could be raised to $3, which would give a gross yearly revenue of $18 000 000, which would be a very large return for a capital of $200 000 000, which is much more than the canal is estimated to cost, including the running expenses and the interest on the money. And as this tonnage is greater than that which was estimated to pass through the Suez Canal, the canal on this continent would be a better investment than the other, and the stock and bonds of the Suez Canal are very much above par.

O. Chanute.—What proportion of the necessary capital will be raised in Europe, and how much do you propose to raise in this country?

M. De Lesseps.—The original capital will be $120 000 000. One-quarter has to be paid up before a company can be formed under the French law. One-half of the capital stock will be allotted to the United States, and the other half to Europe. But in case it is not taken up by the United States I will try and have the sixty millions taken up in some other way. But I wish to have it understood that one-half the stock may be subscribed for in the United States, as the United States have an interest in the enterprise equal to all the rest of the world put together.

Horatio Allen.—Past president of the Society:—I would like to ask a question, so that we may have a little clearer conception of the subject. I understand that the length of the canal from ocean to ocean will be forty-five miles; that a certain portion of that canal will be a deep cut, and that a certain other portion will be ordinary canal work. I would like to ask how many miles are to be cut through, and how many will be a deep cut?

V. Dauzats.—The deep cutting extends for about six and a half or seven miles. The deepest excavation will be about ninety metres; and for this distance of seven miles the cutting may average about 180 feet. In other parts of the canal the cutting will not be of very great depth.

HORATIO ALLEN. – Is the deep cutting entirely in rock ?

V. DAUZATS.—Not entirely in the rock. There is earth over the rock. Col. Totten thinks that the earth may be twenty feet in depth, but in order to be safe the estimate was based on a depth of earth of twelve feet and the remainder rock.

Q. A. GILLMORE.—Will you give some details as to the proposed dam for the Chagres River ?

J. DIRKS.—The height will be 40 metres and the length 1 600 metres. It will form a reservoir capable of holding more water than the greatest flood known on the river. Before a second flood arrives the reservoir could be emptied by the main and the secondary canals. The dam can be sufficiently well built to make it perfectly safe.

ASHBEL WELCH.—Why go to the enormous expense of making a sea level canal across the Isthmus when a canal with two or three locks on each side of the deep cut could be made so much more cheaply ?

M. DE LESSEPS.—If the Commission of Engineers which had gone down to Panama had reported in favor of a canal with locks I should have put on my hat and left the whole project and would have had nothing to do with it. That plan may do for small ships, but when we have vessels now afloat 500 feet long and others on the stocks 600 feet long, it is impossible to say for what you would have to build the locks. Single locks would be slow, and double locks though quicker would be very expensive and require constant repairs. At Nicaragua they intended the use of locks, and with the earthquakes which prevail there the repairs would be ruinously expensive, and even at Panama, where earthquakes do not exist, they would be fatal by reason of the loss of time. I would not have anything to do with a locked canal except for little ships. It is not the proper idea for a grand inter-oceanic canal.

C. BUTLER asked why the San Blas route has not been examined.

M. DE LESSEPS.—The object of the commission was to examine the line accepted by the International Congress ; but in reference to the route referred to by the gentleman, I would say, that although the port on the Atlantic side is very good, that on the Pacific side is not. This line would make necessary a tunnel of, say, seven miles in length, and as the commission had already rejected a route in which there would be a tunnel of three or four miles, why adopt one having a tunnel so much greater in length ?

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

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CLXXXIX.

Vol. IX.—March, 1880.

THE ENGINEERING PROBLEMS INVOLVED IN THE PROPOSED IMPROVEMENT OF THE ERIE CANAL BY INCREASING THE DEPTH OF THE CHANNEL ONE FOOT.

By E. SWEET, Jr., C. E., Member of the Society.

PRESENTED AT THE ELEVENTH ANNUAL CONVENTION, JUNE 17TH, 1879.

The vast economies accruing to rail transportation in recent years from improved administration, depreciated cost of materials and labor and increased durability and effectiveness of machinery and permanent way as well as the improvements being effected in rival water routes, have so threatened the usefulness and permanence of the New York Canal system as to stimulate the friends and patrons of our canals to investigate the improvements most likely to insure their continued supremacy.

The limitation imposed by the State Constitution of 1874, upon canal expenditures which permits no outlay for repairs and improvements upon the canals in any year beyond the gross revenues of the preceding year, as well as physical and economic difficulties environing

the location and termini of the Erie Canal, alike forbid the contemplation of any radical change or any extensive enlargement in it.

For this reason it becomes necessary to confine our attention to improvements which do not necessitate extensive changes in its important structures, its locks, aqueducts, reservoirs and feeders.

These conditions, coupled with the fact that the present large tonnage of the canal consists of boats which almost universally have capacity for a foot greater draft of water without change, have directed attention, by common consent to confining the improvement of the prism to securing an additional foot in depth of water.

To determine the commercial value of this improvement involves the solution of three problems: 1st. What will it cost? 2d. What increased capacity of tonnage, and what decreased cost of transportation will it effect? 3d. Will the present water supply be adequate for the improved canal?

1st. The data for determining the first question are furnished in great detail and in the most available form by the profiles and cross sections and other records of a survey of this canal made by direction of State Engineer Van Buren, during 1876. This survey comprised accurate test levels the whole length of the canal—cross sections at intervals of 66 feet of the prism and banks and the location, dimensions, details of construction and condition of all its structures.

It first became necessary, however, to decide upon the manner of deepening, that is, whether to excavate the bottom of the present channel or to raise its banks. A superficial inspection of the cross sections, diagrams, and of the elevations of the permanent structures, convinced me that the process of raising the banks involved a very much smaller quantity of earth work and far less radical and expensive changes in structures than that of excavating the bottom, and produces nearly twice as great an enlargement of the waterway on account of the slopes and the necessity of leaving benches at the foot of the old walls. The importance of this difference arises from the fact that the resistance to the propulsion of boats in narrow channels diminishes as the water section increases.

The masonry of nearly all the locks, aqueducts and waste weirs is already high enough, and the embankments are generally wide enough to give the requisite height and width to the new banks without adding to their side slopes. Another fatal objection to excavating the bottom is,

that a considerable part of the canal is carried artificially above the surface of adjacent lands, and has its bottom lined with impervious materials to prevent leakage, and consequent damage to farms and other improved property. Excavating the bottom would be a source of danger to all this property as well as to the security of the canal itself, unless the expensive process of additional excavations and replacing the impervious materials on a lower plane were resorted to.

We have, therefore, made estimates for raising the water surface a foot.

This involves the raising of the superstructures and approaches of all bridges, gates of locks, trunks of aqueducts, crests of water weirs, and slope and vertical walls, spillways, and the berme and towing-path embankments, as well as the taking up and relaying of pavement wall and vertical wall-coping on the new towing-path angle.

The estimates are for a towing-path lined with gravel 9½ feet above canal bottom on the inner, and 9 feet on the outer angle, and 12 feet wide, and for berme embankments 9½ feet above canal bottom and 10 feet wide, and to be constructed from materials obtained from the bottom of the prism.

The quantities of all the items of work thus required have been computed in detail, and adequate prices applied to each of them.

The aggregate estimated cost thus derived for the entire work, including a liberal allowance for engineering and contingencies is $1 146 571 45.

2d. The second question—the probable effect of this deepening upon the economy of transportation, depends upon the relative capacity and the relative resistance of boats moving in the present canal, and like boats moving in the deepened channel.

The capacity of boats loaded to run equally near the bottom of the new as of the old channel is evidently increased by the water displaced by the foot additional submersion, amounting to about 1 650 cubic feet, or a little more than fifty tons.

The other branch of this question—the relative resistance offered by the two channels to the movements of boats is a far more complicated problem, the discussion of which is the principal object of this paper.

There is no important problem in hydrodynamics that has received so meagre inductive treatment as this, relating to the propulsion of vessels in narrow channels.

The only experiments on this subject sufficiently comprehensive for

deducing the law of resistance in such channels, are, so far as I know, those of Du Buat and D'Aubuisson. The deductions of these eminent specialists are, however, widely at variance one with another, and with the facts observed as to the propulsion of vessels on our canals.

With a view of obtaining accurate information upon this subject, a series of experiments were made in the fall of 1877, by Resident Engineer Godwin, by direction of ex-State Engineer Van Buren, and a more comprehensive series have been made by me by direction of his successor, Mr. Seymour.

Mr. Godwin's experiments were made with light and loaded boats towed singly and in pairs (one behind the other), partly by horse power, but mostly by a small screw propelled tug. They were made at velocities from 1 to 3¾ miles per hour, and in canal channels of sections varying from 4.09 to 5.61 times the submerged section of boat, and in the broad expanse of the Hudson River.

The resistances were measured by a dynamometer and the speed through the water by an ordinary self-recording tachometer.

These experiments indicated a much higher resistance for the boats towed in the canal by tug than for those towed by horses at the same speed, showing that the current induced by the screw greatly increased the normal resistance of the narrow channel, therefore making all the tug experiments valueless for the purpose of determining the law of this resistance.

Inconsistencies in some of the results obtained both in the experiments made with horses and with the tug, attributable to the inaccuracy of the tachometer, and the small number of the experiments with horse-towed boats, showed the necessity of more extended experiments under more favorable conditions.

Instructed by this preliminary work of Mr. Godwin's, and provided with a dial reading tachometer designed by him, whose revolutions were recorded by electricity under the eye of the observer on the boat, we continued these experiments for two weeks on that portion of the Erie Canal between Canajoharie and Mindenville, New York.

This portion of the canal was selected as the site of the experiments, for the reason that nearly two miles of the level between Canajoharie and Fort Plain are shown by recent soundings to have a section equal and similar to the average channel which would be attained by the proposed deepening, while four miles of the canal at Mindenville very accurately represent the average section of the present canal.

The channels thus selected were subdivided by prominent stakes set 500 feet apart to guide the observers in regulating speed, and to diminish the liability of error in recording the observed resistances.

The canal boat, "Henry L. Purdy," chartered for the purpose of making these experiments is of 240 tons burthen. 96 feet 8 inches long, and 17 feet 7 inches beam, and in model fairly represents the boats in present use on the canal.

She was towed by horses, the resistance measured by a dynamometer and her absolute velocity through the water, determined by the above described tachometer. The co-efficients for deducing the velocity of current from the revolutions made and recorded by this apparatus were deduced by the method of least squares from a series of observations showing its rate of revolution in currents of different velocities, whose rates were simultaneously measured by other means.

The boat was first accurately loaded to a draft of 6 feet, when seven experiments were made in the standard section of the canal 7 feet deep, covering a distance of 50 100 feet, and at velocities ranging from 1.27 miles per hour to 1.95 miles per hour. Then with the same draft of water eleven experiments were made in the enlarged section 8 feet deep, covering a distance of 71 700 feet, and with a range of velocity from 1.39 to 2.09 miles per hour.

The boat was then loaded to 6½ feet draft of water and moved over 24 400 feet of the channel 8 feet deep, at velocities from 1.46 to 2.24 miles per hour, and lastly, loaded to 7 feet draft, towed ever 15 000 feet of the 8 feet channel, at velocities from 1.33 to 2.00 miles per hour. The greatest practical difficulty in this class of experiments arises from the essential lack of uniformity in motion produced directly by animal locomotion. In each of these experiments great care was therefore taken to maintain as nearly uniform a velocity as possible over its entire course, in order to secure probable accuracy in the observed resistance derived from equating a great number of readings from the dynamometer made at short equal intervals of time.

The following tables present the results of all these experiments which are free from known errors, simplified by equating and consolidating the results of those in which the conditions were identical, and in which the velocities varied less than 3 per cent.

Traction Experiments on the Erie Canal, 1877 and 1878.

Name of Boat.	Time.	Distance in Feet.	Absolute Velocity.		Sections		Ratio of Boat to Prism Section.	Depth of Water.	Immersion of Boat.	Weight of Boat.	Weight of Cargo.	Resistance		
			Feet per Sec.	Miles per Hour.	Immersed of Boat. Sq. Ft.	Prism. Sq. Ft.						Observed in Pounds.	Computed by Formula $R = \frac{0.10303\, s v^2}{r - .597}$	Component Parallel to Motion of Boat.
	H. M. S.													
With Horses in Canal near Canajoharie, Aug. and Sept., 1878.														
Henry L. Purdy	0 45 45	5 104	1.86	1.27	105	450	4.28	7 ft.	6 ft.	130 000	467 600	297	278	292
" " "	1 55 20	18 753	2.71	1.85	"	"	"	"	"	"	"	575	590	564
" " "	2 32 58	26 249	2.86	1.95	"	"	"	"	"	"	"	634	657	622
" " "	1 4 50	7 935	2.04	1.39	105	525	5.	8 ft.	6 ft.	130 000	467 600	292	280	286
" " "	0 35 50	5 720	2.20	1.50	"	"	"	"	"	"	"	343	326	336
" " "	2 23 34	33 612	2.30	1.57	"	"	"	"	"	"	"	381	356	374
" " "	2 0 43	20 860	2.88	1.96	"	"	"	"	"	"	"	594	558	583
" " "	0 19 31	3 583	3.06	2.09	"	"	"	"	"	"	"	645	629	632
" " "	0 53 44	6 899	2.14	1.46	113.75	525	4.61	8 ft.	6.5 ft.	130 000	521 120	369	344	362
" " "	0 42 20	7 467	2.94	2.00	"	"	"	"	"	"	"	632	656	620
" " "	0 42 31	8 010	3.14	2.14	"	"	"	"	"	"	"	734	733	720
" " "	0 13 41	1 601	1.95	1.33	122.5	525	4.28	8 ft.	7 ft.	130 000	574 740	350	330	343
" " "	0 55 04	9 714	2.94	2.00	"	"	"	"	"	"	"	678	718	665
" " "	0 23 13	3 691	2.65	1.81	"	"	"	"	"	"	"	602	607	590
With Horses in Canal near West Troy, Nov., 1877.														
S. Evans.....	0 3 30	551.6	2.11	1.44	105	490	467	7.5	6.	129 000	459 600	316	323	304
A. H. Smith...	0 2 00	330	2.47	1.68	102	572	567	7.5	5.9	119 000	434 310	365.5	358	354
S. Evans.....	0 6 00	1 194.6	2.80	1.91	105	"	545	"	6.	129 000	459 600	452	476	435
T. C. Davis....	0 1 24 (?)	330	3.59	2.45	106.4	470	442	"	6.1	116 600	459 200	523.6	....	504
With Tug in River near Albany, Nov., 1877.														
R. W. Stroud...	0 12 50	2 625	5.03	3.44	51			12 ft.	2.9	120 000	140 000	693 8	....	...
S. Evans.....	0 7 00	2 760	4.94	3.37	105			"	6.0	129 000	459 600	1 094.8	...	....
Freddie.....	0 3 00	1 275	5.45	3.72	111	Infinite.	Infinite.	"	6.3	138 500	479 940	1 307	....	....
"	0 6 05	2 625	5.54	3.79	"			"	6.3	"	"	"	....	..

In the last column of the tables I have introduced the theoretical resistances for each rate of speed, with the given ratios of prism to boat sections and extent of immersion computed by a formula which I have deduced analytically from these experiments.

In making this deduction I have assumed that the analytic expression for the law governing the resistance of boats in narrow channels is of the general form indicated by the investigations of Scott Russell and Du Buat, viz.: $R = \frac{av^2 s}{r + B}$ in which R represents the resistance, s the submerged surface of the boat, v the velocity, r the ratio of the channel's water section to the immersed section of boat, and a and B constants determinable by experiment.

Using feet, seconds, and pounds as units, I have applied the method of least squares to the observed values of R, r, v and s, and in all the experiments of 1878, and thus determined the most probable values of a and B.

These values are $a = 0.10303$, and $B = -0.597$.

$$\text{Therefore, } R = \frac{0.10303 v^2 s}{r - 0.597}.$$

On comparing in the tables the observed resistances with those computed by this formula it will be seen that in the experiments made with horse power the differences are slight and readily explained by the difficulty already mentioned, of accurately recording the rapidly varying power exerted by animals.

As before explained, the resistance encountered by the boats propelled by the tug was considerably greater on account of the current induced by the screw. We may, therefore, conclude that the law of resistance within the limits of speed, depth of emersion and ratios of prism to boat section covered by these experiments is for boats of like model and condition of surface, expressed by the equation $R = \frac{0.10303 s v^2}{r - 0.597}$, the units being feet, pounds and seconds. For velocities in miles per hour, this becomes $R = \frac{0.2215 s v^2}{r - 0.597}$.

This formula is readily convertible into the special form given by Du Buat, $R = \frac{PA}{r + B}$ in which P = the resistance of the boat at same velocity in an unlimited expanse of water where P is supposed to be

known for any velocity—Du Buat assigns to A the value 8.46 and to B the value $+2$.

Since both P and R vary as the square of the velocity, and as the area of the submerged surface, sv^2 is a function of both, A in the latter formula $= \frac{P}{sv^2}$.

Taking the mean value of $\frac{P}{sv^2}$ derived from our experiments of November, 1877, in the river, for velocities, measured in miles per hour, we have $A = 6.70$ and the formula of Du Buat becomes $R = \frac{6.70P}{r - 0.597}$.

A close approximation to the value of P may, doubtless, be obtained by applying Scott Russell's rule for vessel propulsion: $R = sv^2 [1 + (4 sin^2 o) f]$, in which s represents the submerged surface of the boat in feet, v, the velocity in miles per hour, o, the mean obliquity of the stream lines, and f the co-efficient of friction for the vessel's surface moving in the water.

By a serious error in the determination of the stream line angles of the boat experimented with in August last, I was led to assign an erroneous value to A in adapting this formula of Du Buat to the results of the above-described experiments, and to my regret it is perpetuated in the annual report of our State Engineer. A careful remeasurement of the boat's model enables us to derive almost precisely the same value for A as that above obtained from the mean of our experiments in a wide expanse of water.

This remeasurement gives 0.526 as the mean value of $sin^2 o$; substituting this value and the numerical values of sv^2 in Scott Russell's formula for P and attributing to f the value $\frac{105}{10000}$, we readily find the resistance the boat would encounter in an unlimited expanse under the conditions of load and speed occurring in any of the experiments. Substituting the value of P thus obtained for any given experiment in the formula $R = \frac{PA}{r - .597}$, and attributing to R and r their numerical values for that case gives $A = 6.68$ or $R = \frac{6.68P}{r - .597}$.

These results indicate that at low velocities the effects of contraction are only felt in channels whose sections are less than 7.3 that of the boats propelled in them. They also show the resistance due to con-

traction to be greater than that found by Du Buat's formula, and that it increases as the ratio of the channel and boat sections diminishes more rapidly than that formula indicates.

We are now prepared to apply this law to the comparative resistance of loaded boats in the present canal, and in the canal deepened as proposed, and thus to determine the advantages of the proposed improvement.

Boats of the standard size and model now in use on this canal have horizontal cross-sections at and above the six feet draft line of a little over 1 600 square feet, and consequently carry a little more than 25 tons for every half foot submersion beyond 6 feet. The submerged surface of these boats, when drawing 6 feet, is about 2 870 square feet; when drawing 6½ feet is about 2 980 square feet, and when drawing 7 feet it is about 3 090 square feet.

The average rate of speed now attained in this canal by boats loaded to 6 feet, towed by two horses, deducting detentions, and making due allowance for currents, is 1.3 miles per hour. Their speed over the ground, however, is 1.54 miles per hour.

They encounter a resistance, according to the law above enunciated, of 292 pounds. The work performed by each horse is, therefore, 20 000 feet pounds per minute.

Two horses, each working at the above rate of 20 000 feet pounds per minute, would tow the boat thus loaded in the improved channel at the rate of 1.39 miles per hour through the water, and 1.63 miles per hour over the ground, encountering a resistance of 277 pounds, thus shortening the trip from Buffalo to West Troy nearly 12 hours.

If loaded to 6½ feet in the enlarged canal their resistance at a given velocity would be nearly 5 per cent. less than when loaded to 6 feet in the present canal; and two horses each working at the rate of 20 000 feet pounds per minute would tow the boat thus loaded in the deepened channel two per cent. faster than when loaded to six feet in the old canal. It also follows that a boat loaded to 7 feet draft in the improved prism, if towed at the above rate of 40 000 feet pounds per minute would move at the rate of 1.27 miles per hour through the water, and 1.51 miles per hour over the ground, with a resistance of 298 pounds. Its trip, therefore, from Buffalo to tide-water would be but little more than four hours longer than that of a cargo 50 tons lighter similarly towed in the present canal.

3d. The water supply.

The proposed deepening of the canal will affect the question of water supply in various ways. It will increase the waste from leakage, filtration and evaporation. The former by reason of the increased head in the levels, and the latter by enlarging their water surface.

It will also, by attracting a larger traffic, increase the demand for lockages, and by increasing the hydraulic mean depth, will create an additional demand to produce the rate of current most beneficial to navigation.

Assuming the apertures of escape to be equally distributed throughout the vertical height of the prism, the losses from filtration and leakage would be increased in the new over the old channel in the proportion of the square root of half the depth multiplied by the depth of the new to that of the old channel. And the losses from evaporation would be increased in proportion to the increase of the surface area. The increased loss due to both these sources will amount to about 18 per cent. of that sustained by the old canal, and added to the latter, will, probably, aggregate for each mile of canal, 250 cubic feet per minute.

If the canal be worked to its full capacity the demand for lockages is 5 500 cubic feet per minute on each declivity. The demand for dry docks and weigh locks may be estimated at 25 cubic feet per mile a minute.

The only other demand for feed water is for producing a beneficial current.

Until recently this important subject has been entirely overlooked on our canals. A very large portion of their tonnage moves eastward, and as the currents induced by the water fed to the Erie Canal are nearly all eastward, *i. e.*, in the direction of the heavy traffic, it is obvious that this may be made highly beneficial to navigation.

The following simple mathematical reasoning demonstrates the effect of currents upon boats differently loaded moving in opposite directions.

Let L represent the length of the canal, x the velocity of the current, v the velocity through the water of the light loaded boat against the current, v' the velocity of the heavily loaded boat moving with the current, t the time required for the up trip, and t' the down trip, and T the time required for the round trip.

Then

$$t = \frac{L}{v - x} \quad t' = \frac{L}{v' + x} \quad \text{and} \quad T = \frac{L}{v' + x} + \frac{L}{v - x}, \quad \text{or} \quad \frac{L \quad (v' + v)}{vv' + (v - v')\, x - x^2}.$$

This equation representing the time of a round trip is evidently perfectly general and true for any assignable values of v, v' and x. The greater value the denominator has the less T becomes, and if v be equal to or greater than v', the value of the denominator is greatest when $x = o$, *i. e.*, when there is no current. Any current opposite the heavy traffic, therefore, prolongs the round trip. To find the minimum value of T, *i. e.*, the shortest round trip, it is only necessary to determine that value of x which renders the denominator $v'v + (v - v')x - x^2$ a maximum. Differentiating this expression and making the first differential co-efficient $= o$, we have $x = \frac{v - v'}{2}$. As the second differential co-efficient is negative the value of $x = \frac{v - v'}{2}$ renders T a minimum.

It follows that an uniform current in the direction of the heaviest traffic, having a rate equal to half the difference in speed of the loaded and unloaded boats through the water, insures the quickest round trip.

We will now proceed to determine, with reference to the deepened canal, the extent of this current, its effect upon transportation, and the demand which it will create for additional feed water.

It appears from the investigations of State Engineer Van Buren, published in his annual canal report for 1877, that, with an average easterly current of .24 of a mile per hour the average rate over the ground of boats towed by 2 horses going east is 1.54 miles per hour, and of those going west is 2.04 miles per hour. Without current the same effective duty of the animals would produce a speed of 1.38 miles per hour for boat loaded to 7 feet draft in the deepened prism going east, and 2.18 miles per hour for the boat carrying the usual load of 50 or 60 tons, going west, requiring 250 hours for the eastward trip, 158 hours for the return trip, and 408 hours running time for the round trip.

The most beneficial current determined by the above *formula* for boats thus loaded and drawn by two horses, each performing an effective duty of 20 000 feet pounds per minute, is .60 of a mile per hour.

At this rate the horses would move over the ground in both directions at the same speed, 1.8 miles per hour, and would encounter the same resistance, 260 pounds, thus requiring 191½ hours each for the up and down trip, and 383 hours for the round trip. Such a current would, therefore, effect a saving of 59 hours in the transfer of the principal cargo, and 25 hours in the time of making the round trip.

It is not practicable, however, to secure an uniform current of this extent throughout the Erie Canal, for the reason that considerable reaches have to be fed from one source, and that on about 15 per cent. of its extent the declivities are opposed to the direction of heavy traffic.

The present supply, however, by raising the Genesee River dam would be sufficient to give a current from .45 to .7, and averaging .60 miles per hour, from Buffalo to Montezuma, and from Little Falls to Albany, and of .30 miles from Rome to Little Falls. With the feed water reduced to the bare requirements of loss and lockage on the westward declivities these currents would make the running time of the above described boats, towed with two horses on the deepened canal, 201 hours going east, and 187 hours going west. Thus making the eastward trip, with 290 tons cargo, in 41 hours shorter time than is required in the present canal for a cargo of 240 tons, and the round trip in 22 hours less time than is now required.

I have dealt with the effects of this improvement on horse-towed boats, because 95 per cent. of our canal tonnage is towed by horses. That it will prove of still greater advantage to steam towing is obvious, as it renders possible the economical attainment of higher speeds than are permissible in the present channel.

The realization of this improvement would have enabled the boats which performed the carrying trade of the Erie Canal last year, employing the same force and the same crews, to have carried, without additional force, with less cost, and in less time, 650 000 tons more freight to tide-water, representing an additional revenue to the State, at present rates of toll, of over $200 000, and on the basis of prevailing freights a net gain to the boatmen of $750 000, besides the advantages to allied interests along the canal and at its *termini*. The benefits of a single year's business, therefore, promise to very nearly repay all the costs of the improvements.

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INSTITUTED 1852.

TRANSACTIONS.

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(Vol. IX.—March, 1880.)

CUSHIONING THE RECIPROCATING PARTS OF STEAM ENGINES.*

DISCUSSIONS

BY CHARLES E. EMERY and JOHN W. HILL.

PRESENTED AT THE ELEVENTH ANNUAL CONVENTION, JUNE 17TH, 1879.

CHARLES E. EMERY.—I was requested, some time since, in the usual way, to discuss this paper at the Convention, and must confess, that in examining it for that purpose I was very much disappointed. There was an opportunity for some one with sufficient information and leisure to so investigate and discuss this subject as to include all known conditions and present formulæ and conclusions of value to others in the profession. I am sorry to say that this has not been done in the paper in question. Some quotations are made from standard works, but the original discussion commences by announcing a quotation for a mathematical analysis to show apparently the relative values of V_1 and V, representing respectively the cost of the power in the engine with and without cushioning, but instead of proof on the subject, we are informed that "V is

* Paper CLXV, by John W. Hill, Vol. VII, p. 183. July, 1878.

evidently greater than V_1." This is not considered evident at all, but the very point to be proved. In fact the writer of the paper afterwards attempts to prove it by the arithmetical solution of a special problem not connected with the mathematical notation, without endeavoring to show that the result is a general one, and would not be different for a change of conditions.

The paper concludes as follows: "The writer is of the opinion that the cushion should be adjusted to realize the highest economy with the least reduction of cylinder capacity."

It could equally well be said that the supply of grease to the engine should be adjusted to realize the highest economy in the use of grease, with the least reduction of the power of the engine, but at the same time it would naturally be expected that a few words would be added, explaining the principles upon which the adjustments should be made to secure such economy, or that sufficient facts would be stated to enable the greasers to draw conclusions of their own on the subject.

The principal considerations relating to the subject of cushioning may be briefly stated as follows: Evidently the clearance spaces* at each end of a steam cylinder must be filled at every stroke with steam at the maximum pressure admitted. This may be done in two ways, viz., by admission of steam directly from the boiler or by closing the exhaust passage before the end of the stroke, so that the back pressure vapor will be compressed and the clearance spaces filled with cushioned steam equal as nearly as practicable to the initial steam pressure in cylinder. In the first case the cost is the quantity of steam taken from the boiler to fill the clearance spaces, and in the second, the quantity of steam required in that particular engine to do the work of compression—supposing the net power furnished to be the same in each case. Generally the second plan will have the advantage, for the reason that the steam required to furnish the aditional power will be worked expansively. There can be no economy of steam by cushioning when there is no expansion, and the full theoretical economy due to cushioning is not attained unless the steam is expanded down to the back pressure where the compression begins, which is undesirable on account of the losses due to interior cylinder condensation during extreme

* This term is intended to include the clearance proper as well as the passages and other spaces between the valve and the piston at the end of its stroke.

expansion.* Hence in practice it rarely occurs that the energy absorbed in cushioning is entirely utilized during the return stroke.† Again, cushioning is an indirect operation so the economy resulting therefrom should be charged with a portion of the friction of the engine, since the total load is increased for the same net load. Cushioning also increases the average back pressure, which under certain circumstances, may be a disadvantage. Moreover, in balancing advantages, it should be borne in mind that if there be no cushion the steam in clearances taken directly from boiler would do some work in an expansive engine. All these, and other conditions, must be fully considered to ascertain accurately the economy of cushioning, and until some one takes the time to formulate them, the common sense view must prevail that cushioning is in general productive of a small economy of steam; that at least it causes no loss within the limits available with ordinary valve gear, and therefore may be used to any practical extent to produce desired mechanical effects. In practice the question of economy becomes of secondary importance compared with the mechanical advantages, particularly for high speed engines. Engineers accustomed to stationary engines with governor cut-off, also some marine engineers, have a habit of finding fault with the distribution of steam in the cylinders of a locomotive, and the writer of the paper shows the same disposition by criticising parties who are apparently using similar features on a stationary engine. The indicator diagrams do not look well judged by ordinary theoretical standards, but when all conditions are considered, both theoretical and practical, the true *scientific* result is reached and the valves and gears are found to be very nearly perfect for the purpose. The introduction of the link motion on locomotives over twenty-five years ago immediately produced a remarkable saving in repairs, due greatly to a reduction of shocks in the connections by cushioning, which with the remarkable simplicity of the mechanism, caused its general adoption. The points most criticised are really advantageous for the following reasons: All locomotives necessarily have cylinders proportioned to the adhesion, so as to start the trains and surmount the grades, and such cylinders are altogether too large for the ordinary work, particularly with passenger trains.

* See article on Compound and non-Compound Engines. Trans. Vol. III, p. 368, § 6.

† The paper states (p 186): "Theoretically there is no loss of power by this process (cushioning), as the energy absorbed in cushioning the steam is given up when the piston begins the opposite stroke." The expression "begins," &c., is faulty, but the idea intended to be conveyed is a popular view which is in general incorrect, as explained.

By "linking up" the cushioning and expansion are both increased and the former, as well as the early release act efficiently to reduce the effective size of the cylinder without requiring the cut-off to be made too short for economy. The early release also permits the escape of the steam at high speeds.

The action of the link motion is due, of course, to the lap valve, and it should not be forgotten that the proper proportions of such a valve were ascertained from numerous experiments by Mr. D. K. Clark, and published in his "Railway Machinery," before the link motion was fairly introduced in this country, and that, consequently, the continual tinkering with the valves practiced on some roads is almost entirely inexcusable. On one very prominent road the passenger engines are actually running with ¾-inch lap, and the only excuse given for it is that the trains had got heavy, and that they had to cut the lap down in order to let the men run in the same notch as before, and upon asking why not leave the lap and hook down further, they really appeared to think that in that way they would use more steam than with less lap and the lever further back. Fortunately, such proceedings are an exception on most roads.

A prominent engine builder once put trip cut-offs in the steam chest cover of a locomotive, the engine being run with links down. No economy resulted, and I was consulted, so the builder, instead of trying to persuade the master mechanic to allow him to cut the lap off the main valve as he intended, sent the apparatus to the scrap heap. I would not have it understood that there is no chance for improvement in locomotives, only that certain criticisms are unfounded when all things are considered. The valves are getting so large that it will pay to balance them when an arrangement sufficiently simple is found. Where fuel is dear, feed water heaters with part of the exhaust steam (requiring larger boilers on account of reduction in draft) will come into use, and a simple combined lever and screw reversing gear thus happen to be adopted on roads when the master mechanic is the inventor. The greatest successes for a long time will be due to good proportions and careful management.

For condensing engines the lap valve and link motion also have advantages that are not duly appreciated. The power required is so nearly uniform that the inside lap can be regulated to give the release exactly as desired, and the extreme cushioning due to comparatively

short points of cut-off is hardly noticed on account of the low back pressure, and is, moreover, advantageous in producing smoothness of working and screening the interior of the cylinder for a portion of the stroke from the refrigerating influence of the condenser through the exhaust steam.*

JOHN W. HILL.—It is, or should be, apparent to Mr. Emery that the locomotive is not under consideration in the paper, for locomotives, as a class, are not engines that run at uniform speed. Whilst variable cushion, by reason of variable speed, is necessary in the locomotive engine, excessive cushion (compression) to reduce cylinder capacity is not sought; and the best practice in locomotive valve motion at the present time makes the inside or exhaust lap just sufficient to insure a closure of both steam parts when the slide valve is at mid travel; as a consequence, the closure of the exhaust is made as late as possible with a given position of the link.†

If the slide valve and link motion were capable of such an effect the power of the locomotive engine and capacity of cylinder could be sufficiently varied by shifting the links with constant exhaust closure, and were locomotive engines to operate at constant speed, Mr. Emery would no doubt agree with the writer that a constant compression should obtain, however great the disagreement might be upon the amount of cushion for given initial pressure, speed and weight of reciprocating parts.

Variable compression in the locomotive engine is desirable, and the variation (other conditions the same) should be as the square of the speed; but it is not pretended that this condition is met in the locomotive valve gear, for with any position of link and initial pressure, the speed will vary between widely separated limits, depending upon the load and plan and profile of track.

The steam diagram of maximum economy, so far as the compression line affects it, is when the compression to initial pressure is had with least reduction of cylinder capacity; but in engines working steam at five or more expansions, the reduction of cylinder capacity to obtain compression to the initial pressure is a very large percentage of the total cylinder capacity, and in a practical point of view, is scarcely justified

* See paper on "Steam Engine Economy," Transactions, Vol. VII, page 63.

† Tests of a Baldwin Locomotive. Journal of the Franklin Institute, April and May, 1879. Dimensions of Engine and Diagrams.

by the resulting economy of performance, as compared with the economy to be obtained by a reduced cushion with an increased effective capacity of cylinder. Hence the opinion expressed by the writer at the close of the paper.

It is well known to steam engineers that compression in steam engines is material to the economy of performance, and that it is of sufficient importance to be well understood. That it is not so understood is well proven by the literature upon the subject. The only intelligent consideration of the problem that the writer is familiar with being by Mr. Charles T. Porter, and his views, while elegant in theory, are incapable of demonstration, by reason of his neglect of conditions subsisting in steam cylinders in practice, in that he assumes no pressure, or what is the same, a constant pressure upon the steam side of piston at exhaust closure, when, in fact, this pressure is subject to a wide range, and an adjustment of cushion by Mr. Porter's formula must fail in realizing desired results.

ERRATA.

Transactions American Society of Civil Engineers. Vol. IX, January, 1880. Inter-Oceanic Canal Projects, by Walton W. Evans. Page 20, third line from bottom: instead of fifteen *metres* to the mile, read fifteen *inches* to the mile.

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(Vol. IX.—April, 1880.)

INTER-OCEANIC CANAL PROJECTS.*

DISCUSSIONS

By J. DIRKS, A. COUVREUX *fils*, ASHBEL WELCH, WILLIAM E. MERRILL, CHARLES MACDONALD and T. C. CLARKE.

Discussion by JUSTIN DIRKS.

Some criticisms have been made on the prices for various kinds of work on the Panama Canal, which were adopted by the Technical Committee of the Paris Congress, of which I had the honor to be Chairman.

These prices are as follows :

		Francs per cub. metre.	Cents per cub. yd.
Earth	For dry excavation	2.50	38.5
Rock of mean hardness	" "	7.	108.
Hard rock	" "	12.	185.
For excavation, including pumping, rock of any kind		18.	277.
For dredging and excavation under water, mud and alluvial soil		2.50	38.
Dredging hard soil		12.	185.
Removal of rock		35.	539.

*Inter-Oceanic Canal Projects, Vol. VIII, p. 311 (November, 1879). Vol. IX, p. 1 (January, 1880). Vol. IX, p. 47 (February, 1880). Vol. IX, p. 87 (March, 1880).

It has been stated that these prices are less than they should be. I beg to ask your kind attention to a statement of the basis of the estimates of prices.

The price of 38.5 cents per cubic yard for excavation or dredging of earth and alluvial soil, was fixed in the first place by Messrs. Wyse, Reclus and Sosa. It was submitted to practical men : First, To Mr. T. A. Ros, one of the largest contractors in the Netherlands, who said that the removal of earth, either by excavation or dredging, ought never to cost 38 cents per cubic yard, even if all the machinery and workmen had to be brought from abroad.

In fact, Mr. Ros stated to me, on another occasion, that he would be ready at any time to make near Utrecht a cutting of six millions of cubic metres (say 7 800 000 cubic yards), including a maximum haul of 2 000 metres to a spoil bank at 0.70 francs per cubic metre, or about 11 cents per cubic yard.

A smaller quantity of soft mud to be dredged, transported by boats, discharged into the water, dredged again and pumped over into a secluded area of water, was contracted for between myself and Mr. T. Van de Velde, at the price of 18 cents per cubic yard.

Mr. Dauzats, who sailed this morning for Havre, states that at the Suez Canal the cost of excavation or dredging of such material never reached 15½ cents per cubic yard.

There is such an enormous difference between 11, 15.5, or even 18 cents per cubic yard, and the adopted price of 38.5 cents, that the last named seems as if it ought to cover all contingencies.

Mr. Dauzats stated to me that Messrs. Lull and Menocal were satisfied to put the prices for the Panama Canal plan at 35 cents for earth and 40 cents for soft mud.

For excavation of rock of mean hardness, where pumping is not required, the price of 7 francs per cubic metre ($1.08 per cubic yard), was fixed by Messrs. Wyse, Reclus and Sosa, and was approved by M. Couvreux *pere*, the well known French contractor, in the following terms : "Your prices for *any* rock to be excavated and removed, without pumping, will be very remunerative. It seems to me, upon examination, that they might even be reduced, in view of the methods which will be employed in excavation."

This remark was intended to apply also to the price of 10 francs per cubic metre ($1.54 per cubic yard), for the excavation of hard rock where

no pumping was required, as proposed by Messrs. Wyse, Reclus and Sosa, and it therefore covers the case of the price of 12 francs per cubic metre ($1.85 per cubic yard) fixed by the Paris Congress.

Mr. Ros states that basalt from the Rhine and limestone from Tournay, in Belgium, cost less than $1.85 per cubic yard, even including transportation by water for a distance of 200 kilos (125 miles).

Mr. Dauzats informs me that the prices set by Messrs. Lull and Menocal in their estimates of a Panama canal, for all kinds of rock above water, were only $1.25 to $1.50 per cubic yard, or 35 to 60 cents less than the Paris Congress prices.

For excavation of rock where pumping is required, the price of 18 francs per cubic metre ($2.77 per cubic yard) was obtained simply by adding 6 francs per cubic metre (92 cents per cubic yard), to the price for dry excavation.

There is room for difference of opinion as to the sufficiency of this addition to cover unforseen contingencies. I would say on this subject—First. that a part and possibly a large portion of the rock to be excavated where pumping will be required, will prove to be of mean hardness ; but the price for all such is fixed at 92 cents more than for hard rock.

Secondly, that additional price of 92 cents per cubic yard, for pumping only, seems rather high. I never experienced pumping as costly as this, even in loose sand. There is a fair chance that the pumping at Panama will not prove more expensive than that at the recent excavations near Hell Gate, where, as I was informed by General Newton himself, the maximum amount of water encountered at a depth of 26 feet below ordinary low-water level was 200 gallons per minute.

The prices of the Paris Congress were adopted, therefore, after long discussion, and with the full approval of your distinguished countrymen Colonel Totten and General Wright, as *thoroughly* high figures, in order to ensure full security.

I beg to observe further, that the Paris Congress only approved these prices. They were established by the first sub-commission of the Congress, composed of the following well known, thoroughly practical engineers and contractors, namely :

M. Cotard, late Engineer of the Suez Canal contractors.

M. Couvreux *pere*, contractor for the Danube works, the canal be-

tween Ghent and Ter Neuze, and the harbor works at Antwerp, and late Contractor on the Suez Canal.

M. Lavalley, Chief Engineer of the Ponts et Chaussées and late General Contractor for the Suez Canal Works.

M. de Lepinay, Chief Engineer of the Ponts et Chaussées, who designed and executed several works in the Mexican Republic.

M. Ruelle, Chief Engineer of the Ponts et Chaussées and Director of Construction of the Paris, Lyons and Mediterranean Railway.

M. de Garay, Civil Engineer, General Director of the Desague works of the Valley of Mexico.

M. Louis Favre, contractor for the St. Gothard Tunnel, the completion of which has just been telegraphed from Europe. [Most unhappily, this clever and self-made man died a few months ago, shortly after the closing of the Paris Congress.]

The above names speak for themselves. It seems unnecessary, therefore, to dwell longer on the question of prices, as from what has been said it is plain that the last Committee wished to exclude any figures which might afterwards prove too low. So fully satisfied were they that this object had been accomplished, that they did not hesitate to reduce the allowance for contingencies to the usual ratio of 10 per cent., which in this case amounted to 76 millions of francs, or about 15 millions of dollars.

Though my professional colleagues of M. de Lesseps' Staff, left this city this morning, I am prepared of course to discuss any remarks that may be deemed advisable by members of this Society.

[In reply to questions asked by several of the members present at the meeting, and also to questions sent by letter by A. G. Menocal, Member of the Society, Mr. Dirks made the following answers :]

What is the nature of the soil or formation at the site of the proposed dam across the River Chagres ?

Mr. J. Dirks.—The soil at the site of the proposed dam across the River Chagres is a stiff clay. There seems to be no sand in it at all. Most of the clay in Holland has considerable admixture of sand, but this seems to be purely clay. It is very hard, and I consider that it will afford a sufficient foundation for the dam without excavating to the rock, some 20 feet below.

Have a sufficient number of borings been taken to ascertain with

certainty the nature and quality of the rock on which the foundations of the dam will rest? If so, what is the character of the rock?

Mr. J. Dirks.—The rock at the site proposed for the dam is hard rock, and in my opinion sufficiently strong to sustain the dam, and such stone as may be excavated can be used in the construction of the dam. I regret that Mr. Boutan, the engineer who made the special examinations as to these points, has been compelled to return this morning to France, and that therefore the information given you this evening is not as full as it would be if he were present.

A number of borings were made to the rock, at the site of the proposed dam, as stated in the report of the technical commission.

Vice-President Chanute.—I desire to say that M. De Lesseps promises to transmit to this Society a full report of the results of the late technical examination of the line proposed for the Panama Canal. But as this involves the collation of the records and field notes of all the parties engaged upon the surveys, it will be some time before it will be possible to furnish the report and send it to us.

A Member.—Has a detailed survey been made of the water-shed of the Chagres above the site of the dam?

Mr. J. Dirks.—The examination of the water-shed of the Chagres was made by M. Dauzats, the Engineer of the Suez Canal, and the dimensions of the proposed dam were determined by him in consultation with the other members of the technical commission. A plan has been completed on a very large scale of the part to be covered with water, upon the completion of the dam, and its cubic contents, which are estimated at 1 000 000 000 cubic mètres, have been calculated.

By what means was the last flood of the Chagres measured at its different stages of rise and fall, so as to determine accurately the amount of water passing through a given section?

Mr. J. Dirks.—The information as to the flood of the River Chagres was collated by Col. Totten from data given by officials of the Panama Railroad, which those officials state were very carefully secured. Col. Totten prepared a very full and very interesting memoir, in which he showed in detail the flow at various points, and calculated the total quantity of water, which proved, if I remember right, somewhat less than the cubical contents of the proposed impounding reservoir back of the dam at Gamboa.

What is the maximum carrying capacity of the proposed artificial channel from the reservoir to the sea?

Mr. J. Dirks.—The capacity of the proposed artificial channel from the reservoir to the sea is two hundred cubic meters per second. The time required therefore to empty the impounding reservoir would be, *calculating* 1 000 000 000 cubic metres, divided by 200 which gives it to us in seconds—about 58 days, provided no more rain fell in the meantime. The management of the flow, whether into the main canal or the subsidiary channel, will doubtless be properly arranged by the Engineers who may be engaged upon that service.

How is the Obispo river going to be disposed of? Will it be made to discharge into the basin or directly into the new channel?

Mr. J. Dirks.—The Obispo is but a small stream. There would be no great harm in allowing it to flow into the canal, but if upon further investigation this is thought objectionable, it can be swung across the canal on a draw-bridge, and allowed to flow through a trough when no vessels are passing, being kept back at other times by a sluice-gate.

What is the estimated time required for building the dams and the artificial channels?

Mr. J. Dirks.—The time estimated as requisite for the completion of all the works, is 8 years; if driven with vigor it can be done in that time.

By what methods is it proposed to dispose of the waters of the Chagres and other streams during the construction of the dam and new channels, so that the work on the canal can be proceded with from Matachin to Aspinwall?

Mr. J. Dirks.—It will not be hard to manage the Chagres during the progress of the work. In Holland we generally allow the waters to rise in a reservoir behind a dam at the same time that we build it, and it will probably be so managed at Panama, the dam being begun in the dry season and raised uniformly over its entire length, so that the water shall raise at the same time, any surplus, or apprehended surplus in time of rains, being let off by the artificial channel.

Have any provisions been made to keep the canal free from the Rio Grande? If so, what do they consist of, and under what heading do they appear in the estimate?

Mr. J. Dirks. The Rio Grande is mainly a tide-water river; its watershed and drainage is small, and but little water except that from the

tide comes into it; cut that off, and it will almost disappear. We might turn its flood-water into the canals without inconvenience.

By what method is it proposed to drain the country on the south side of the canal, from the dividing ridge to the River Trinidad, a distance of not less than 25 miles by the line to the canal?

Mr. J. Dirks.—There are no streams of magnitude in the country referred to, and such drainage as may be necessary can easily be provided for.

How many tide-locks are proposed? and can ships approach and leave the canal through the tide-lock at all states of the tide?

Mr. J. Dirks.—One tide-lock is proposed at the Pacific end of the canal, and it is intended to place its bottom at such elevation with reference to the tides as will enable vessels to enter it at any time.

What is the estimated time for a ship to pass the tide-lock?

Mr. J. Dirks.—One hour has been allowed for passing the tide-lock.

Can the tide-lock, in your opinion, be built for the estimated sum of 12 000 000 francs?

Mr. J. Dirks.—I am not a contractor, but if I were, I think I would be quite ready to undertake to build it for that sum. From the experience of the cost of the locks of the North Sea Canal, I should say that the estimate was safe.

Would it not be fair to add to the estimates made by the Technical Commission, and based on the prices fixed by the Congress at Paris, the commissions to bankers, interest during construction, indemnification to the Panama Railroad and to the Company owning the concession from the Colombian Government, and a per centage for contingencies, before a promise is made as to probable profit on capital?

Mr. J. Dirks.—The Technical Commission was requested simply to make estimates of the probable cost of the work; it was not requested to, and consequently did not, consider the subjects of commissions to bankers, etc. There is added for contingencies, as will be seen by reference to the report of the Commission, the usual ten per cent., or 76 000 000 francs to the total estimated cost.

What is the time estimated as required to complete the proposed canal?

Mr. J. Dirks.—Eight years.

Vice-President Chanute.—Mr. A. Couvreux *fils*, partner of one of the largest engineer contracting firms in Europe, which executed much

of the works on the Suez Canal, has kindly offered to give us an account of Inter-Oceanic Canal enterprise since the Paris Congress, and of the late expedition to Panama, of which he formed a part, having subsequently come to the United States with M. De Lesseps. He will make his address in French, and I will translate it into English as he proceeds, to the best of my ability.

Discussion by A. Couvreux *fils*.

In calling the Paris Congress, M. De Lesseps addressed about 300 invitations to distinguished engineers, and to the persons who were thought to be best fitted to take part in its deliberations.

Of these, about 100 attended in May last, and among them, Admiral Ammen, M. Menocal, and several other gentlemen well and favorably known in this country.

After a full and free discussion in that Congress, the Panama route was decided upon, and M. de Lesseps was urged by his friends to take the direction of the enterprise. This he readily consented to do, and he took steps to organize a company to execute the works.

A "Compagnie Civile," or a syndicate as you call it in this country, had already been formed under the presidency of General Turr, and had obtained through its representative, Lieut. Com. N. B. Wyse, a concession or charter from the Colombian Government conferring certain rights and privileges for the building of a canal across the Isthmus of Panama, as well as proposals for a contract for the purchase of the Panama Railroad from its owners.

After the close of the Congress, this syndicate agreed to transfer all its rights to M. De Lesseps, including its charter, concession of lands, project of contract with the railroad, etc. Thus M. De Lesseps became the sole proprietor of the right and charter to build a canal across the Isthmus of Panama.

The numerous friends of M. De Lesseps gathered around him, and made up a sum of $400,000, which they placed at his disposal to defray the expenses of verifying the surveys, and organizing the Canal Company. In consequence thereof, he was enabled to make the deposit of $150,000, which the concession from the Colombian Government required should be paid into its hands, in silver, as security for the undertaking of the works, and to secure certain rights.

He then opened subscription books, and offered to the public an

opportunity to take the stock of the company which was to complete the canal. He failed, however, in obtaining the requisite amount of capital.

This took place so soon after the closing of the Congress, that the American newspapers giving an account of the reports of the American Delegates, and attacking the resolutions of the Paris Congress adopting the Panama route, had not arrived in Europe; but it was known by telegraph that serious opposition to the canal existed in the United States, and this threw a cloud over the enterprise, which, combined with opposition at home, was sufficient to defeat the subscription.

M. De Lesseps had entered into communication with the leading banking houses in France, as well as those of other parts of Europe. A practice has lately sprung up among bankers by which, instead of acting as agents upon a commission for the receipt of subscriptions, they buy large blocks of the stock of new companies on private terms, and then sell them to the public at an advanced price. Now, M. De Lesseps is opposed to this; he desires that each stockholder shall acquire his stock at par, instead of paying to bankers a profit of 20 to 30 per cent., and he refused the terms which were offered him. Whereupon all the papers interested in banking or controlled in one way or another by the bankers, began to make fierce attacks upon M. De Lesseps and his scheme, which they kept up day by day, and to which he never replied. Sometimes representatives of the less reputable of these sheets, called at the office of the Suez Canal, and showed articles already in type, favoring his project, which they offered to publish for a consideration. He refused such offers, whereupon an article favoring the Nicaragua route would generally come out of the other pocket, and an offer to suppress it be also refused. Moreover, there was no popular local interest to appeal to. When the Suez Canal was organized, it was expected largely to increase the Mediterranean commerce of France, and large subscriptions were obtained at Marseilles, and in the South of France; while in the case of the Panama Canal, the advantages were remote, and the work was in a foreign country, where it would be of equal advantage at least to other nations.

Thus the first attempt to organize the Panama Canal Company did not succeed, but nevertheless M. De Lesseps did not abandon his scheme. His views were wider. He applied to M. Dirks, and to other engineers, and asked them to join him in organizing an expedition to verify the surveys at Panama, and to come to the United States, and with their aid

he organized the "International Technical Commission," which took up the whole question as left by the Congress.

Meanwhile M. De Lesseps, who always seeks to obtain information from practical men, and to consult those who have been in the habit of carrying on great enterprises, had previously applied to our contracting firm*, and asked us to send a representative to examine the country and the climate at Panama. We sent M. Gaston Blanchet, one of our engineers, who arrived at Panama early in September, 1879, and he soon cabled us, from what he saw, that there was no material difficulty in the way of a sea-level canal, but that it would be necessary to make careful and complete surveys, to determine the plans to be adopted, and the character of the rock to be excavated.

Upon receipt of this despatch, M. De Lesseps sent out a mining engineer, M. Jegou, the same who conducted so successfully the borings in the Algerian "Chotts" in the expedition of Commander Roudaire. He took with him six sets of boring tools, so arranged that they could penetrate to a depth of 200 feet each, and Messrs. Duflos and Barbier to take charge of their working. He also took with him Messrs. Marolle Brothers, who are experienced levellers and suveyors, to aid in the work.

During the time that this party was organizing, M. Blanchet was sending from Panama reports by every mail to Paris, all of them uniformly favorable in character, as to the practicability of the canal, but about this time the cable broke, and M. Blanchet, receiving no advices or instructions from Paris, and not knowing that a party was about to sail, went back to France, in accordance with his original instructions.

Accordingly, when Messrs. Jégou, Duflos, Barbier and Marolle Brothers arrived at Aspinwall, M. Blanchet was no longer there, but they met M. Sosa, an eminent Colombian engineer, educated in the United States, and a very agreeable gentleman, who was thoroughly familiar with all the surveys made by Lieut. Wyse and others. He had pluckily gone from Panama to Aspinwall during the great flood in November last, most of the way in a canoe, and had measured, on his way down, the speed of the current and the height reached at several points. His measurements and deductions are somewhat at variance with the conclusions of Col. Totten, as presented by the latter to the Technical Commission.

*Couvreux, Hersent & Co., contractors for the Suez Canal, the Canal from Gand to Terneuzen, the Port of Antwerp, the works on the Danube, etc., etc.

Acting upon M. Sosa's suggestions, M. Jégou and the other gentlemen whose names have been mentioned, took up their positions at various points on the Isthmus, and began boring, operations which are not yet completed.

M. Blanchet fortunately arrived in France before the sailing of M. De Lesseps, and he immediately returned to Panama with him and the Technical Commission, being convinced that they could only bring back from America a favorable report. His perfect state of health afforded convincing proof that Panama could not be the charnel house for Europeans which it has generally been represented to be.

Our expedition sailed from St. Nazaire on the 8th of December, 1879, in the steamer Lafayette. During the ocean trip the Technical Commission held several sessions. At the first meeting M. De Lesseps presented a programme of operations, consisting of the eight questions which are answered in the report of the Commission.

M. De Lesseps stated that it was not his object to ascertain exactly what would be the cost of the canal, including the expenses of management, interest and discounts, purchase of the railroad and other properties, etc., etc.; but that he desired the Commission to confine itself to the technical portion of the subject, and to inform him whether the figures presented by Lieut. Wyse, his longitudinal and cross sections, and computation of cubical quantities, were correct; and whether, in the judgment of the Commission, the works could be executed at the prices fixed by the Paris Congress. He asked for a report at the end of January.

The Commission was somewhat dismayed at the amount of work that this involved. Whereupon it was resolved that all should work, each accomplishing as much as he could. M. Dirks kindly consented to calculate personally the cross sections, in addition to taking charge as the head of all the surveying parties. He worked night and day, especially towards the last, as he wanted to be certain of the correctness of all the figures. The work for the surveys of the 45 miles of canal was divided up among five parties.

M. Pierre Marolle was placed under my orders to take charge of the surveys, from kilometer 73, the terminus at Panama, to kilometer 55, at the head of the Rio Grande, and explored the valley of this stream between those points. We had with us two aids or interpreters belonging to the country, and fifteen negro laborers.

The second party was directed by M. Jégou. He surveyed the

Culebra ridge or great summit cut, from kilometer 55 to kilometer 40, and was assisted by two local aids or interpreters, and fifteen negroes.

The third party was under the charge of M. Dauzats, who, with Messrs. Ortega and Ossa, and the required number of aids and laborers, took special charge of the surveys for the projected dam across the Chagres River at Gamboa, and the valley to be flooded above it by the dam.

The fourth party surveyed the location of the canal along the Valley of the Chagres, from kilometer 40 to kilometer 20. It was in charge of M. Sosa, who was assisted by M. Fontan, Engineer of the Ecole Centrale of Paris, two aids or interpreters, and fifteen or twenty negroes.

The fifth party took charge from the 20th kilometer to the Atlantic Ocean, in the lower valley of the Chagres. It was in charge of M. Albers, with Mr. Charles Marolle and the usual number of aids and laborers.

We arrived in Panama on the evening of the 31st December. The first three days were taken up in receptions and dinners. Nevertheless the mornings were employed in digesting—our instructions and organization. Each day a session of the Commission took place, M. Dirks presiding.

On Monday morning, the 4th of January, 1880, all the parties started for their work by the seven o'clock train.

And here we wish to express our thanks to the managers of the Panama Railroad Company, who at this and all other times, placed their line and trains at our disposal, in the most courteous and efficient manner.

Each party selected and established its headquarters at some point most convenient for carrying on its work.

In accordance with instructions previously received, every two or three days, the head of each party went to Panama, which was established as headquarters, to present a report of his progress, and write out the contents of his notebooks. Thus we managed to get 58 cross sections of the valleys. As soon as all the parties had returned to Panama, there was a full session of the Technical Commission.

At this M. Dirks exhibited a compendium of the information obtained by the different parties, and we made the calculations of heights, and computations of various quantities. This, however, took but a minor part of the time consumed; most of it was spent in discussion of the

plans and of the execution of the works, as well as the prices which should be estimated for them. It was thus, as M. Dirks has explained, by a comparison of views, and discussion of methods and prices, that the lump estimate of twenty millions of dollars for the dam across the Chagres was arrived at. This large estimate, so stated, should indicate to you that the various members of the Commission were by no means agreed as to the cost of the various detailed parts of such a dam. As for myself, I believe that further examinations will disclose that there are other locations where the projecting spurs of the mountains afford a better position for the dam, and where a less expensive structure can be substituted for the one estimated for.

At length the Technical Commission arrived at definite conclusions upon all the questions which had been put by M. De Lesseps, and on the 14th of February we had the satisfaction of signing the report and placing it in his hands.

Immediately thereafter most of the Technical Commission left Panama for the United States with M. De Lesseps, leaving instructions with M. Sosa and other gentlemen whose names have been mentioned, to complete some special surveys, and especially the borings.

This will require some little time, as the borings begun in November were not completed in February to the full depths required in order to obtain a full and clear geological section down to the bottom of the canal, of all the rocks of the entire Isthmus. All the records of these borings, as well as the samples obtained in them, and during the progress of the surveys, will be sent to M. Boutan in Paris, who has special charge of the geological branch of the examination, and who will make a full report thereon, so that intending contractors may be fully advised of the materials to be encountered.

It was upon the receipt of the report of the Technical Commission that M. De Lesseps drew up the circular addressed to American bankers, who may take charge of receiving subscriptions to the shares of the Inter-Oceanic Canal Company.

It has been asked why, when the Technical Commission reported the probable cost at $168 000 000, M. De Lesseps proposes to organize his company with a capital of only 120 millions of dollars.

In the first place, it is certain that material economies can be made in the execution of the works, from the estimates presented by the Commission, for it will be noticed that the prices given are materially higher than those adapted for the estimates of the Nicaragua project.

Moreover, it is very certain that if the 120 millions of dollars, which M. De Lesseps proposes to raise, are not sufficient to finish the canal, he can always put a mortgage upon it. Therefore it seems unwise to start with a larger sum than 120 millions, especially as interest will be lost on what is kept on hand, and it may not be necessary to spend the whole of it.

M. De Lesseps told me to express his regrets that he could not be present on this occasion, as he has to attend two meetings this evening. From the reception which, much to his gratification, he has received in New York, he has great confidence in the future success of his enterprise. For in point of fact whither is the discussion now leading—is it to the adoption of his project for a canal at Panama, or of the Nicaragua route? It does not seem to favor the latter, yet if its friends still have confidence in its merits, let them raise the capital and build the canal there.

At Panama three schemes are presented, a sea-level canal, a canal with locks, and a marine railway.

The marine railway proposes to transfer ships on cradles from one ocean to the other, but the author of the project does not state how many trips he can make per day, nor how safely he can transfer great ships, nor what will be the cost thereof.

A canal with locks would be as practicable at Panama as anywhere else; it would save large expenditures in the first building of it, but M. De Lesseps has decided never to have anything to do with a lock canal for ships, and his experience at Suez has convinced him more and more that a canal with locks will not answer the requirements of modern commerce and of the great ships in which it is transacted. During certain seasons of the year, when the large crops of California come to market, there might be days when sixty or more ships, delayed by storms, would arrive and want to pass at once. How could they be transferred through locks without great detention to some of them? Now wheat, indigo and similar shipments, are subject to rapid and great changes in price, in the markets of the world, so that the delay of a single day may cause much loss to the shipper or the consignee. What would he think of the locked canal, if the detention of his vessel at Panama delayed its arrival until his competitors had glutted the market, and put down the prices of his shipment?

It is quite certain that a sea-level canal will be more costly than a canal with locks, but should this consideration be urged, while bearing in mind the probable returns of the enterprise.

Now, according to the statistics presented by M. Levasseur to the Paris Congress, the annual traffic to be expected amounts to six millions of tons per year; this would be charged at the rate of $3 a ton, thus yielding a revenue of $18 000 000 per annum, which would give quite a sufficient return to the holders of the shares. Perhaps not to American investors, who are accustomed to great profits, but certainly a sufficient return to European stockholders, where money is cheap.

Besides, if $3 a ton is not sufficient, the canal company may charge a higher price. It is not, however, believed that the charge will be made more than $3 a ton. M. De Lesseps is opposed to any higher charges. He established a price of $2 a ton at Suez, and it has remained at that ever since.

M. De Lesseps is asked why he does not establish an office for his company in America. His answer is that the principal office must be in that country which furnishes most of the funds, and that if a majority of the capital is subscribed in the United States, he will be very glad to transfer the seat of his operations to the City of New York, or some other American city.

As soon as the compilation of the various notes of the cross-sections, borings, &c., are completed, and the reports, maps, &c., are published, the Technical Commission will take special pains to send full sets of them to the American Society of Civil Engineers.

And now, in conclusion, allow me to thank the society for the kind, the more than kind, the hearty reception, which has been extended to us in New York, and for showing us the very interesting American works which we have seen. We did not expect, we were not prepared, for so cordial a reception. In fact, we had been told that the Americans looked upon M. De Lesseps with suspicion, and we had no idea of the boundless hospitality, wide as your own country, which awaited us. Messrs. Boutan and Dauzats, who sailed this morning for Europe, were very careful to impress upon me before they left, that I must say at least this much to you, and to convey their thanks, at the same time as my own, for the great kindness, which you may be quite certain shall never be forgotten by us.

I have left with the secretary two volumes, containing drawings and photographs of some works executed by our firm, the acceptance of which I beg from the Society.

G. W. Dresser moved that a vote of thanks to M. Dirks and to M.

Couvreux be passed, for the interesting discussion which they have given of the question, for their patience and kindness in answering questions, and for their able discourses. Seconded, and carried unanimously.

M. Dirks.—I wish to say that my stay in New York has been almost the happiest period of my life. That I hope that I may have the good fortune to come back again to "New Amsterdam," and that should any of you ever visit old Amsterdam, you call on me—that's all.

Discussion by Ashbel Welch.

Mr. President and Gentlemen,—You will remember that I asked M. de Lesseps the other night: "Why go to the enormous expense of making a sea level canal across the Isthmus, when a canal with two or three locks on each side of the deep cut could be made so much more cheaply?" In his answer he mentioned two objections to the locks; one was the cost of maintaining and operating them, the other the detention of the vessels. He remarked that locks might do very well for ships of small size, but not for such as would navigate this canal. In this the veteran diplomat follows public opinion, which, whatever his own opinion may be, his position compels him to follow.

I propose to point out, first, the great saving that may be effected by putting in three locks, each of 20 feet lift on each side of the deep cut; second, that the annual costs and detention by the locks will be very small in comparison with the saving; and third, how the largest ships that ever floated can be handled with as much certainty and safety as a rowboat.

I admit that if animal power, or the steam power afloat were to be used in handling the vessels, or human hands were to operate the locks, as I suppose is now the case on all canals in the world but one, I should agree with M. de Lesseps, or rather with present public opinion, that locks should be avoided at whatever cost.

Though I am sure the work on this canal cannot be done for the prices estimated by the engineers, I shall for the present purpose admit that those prices are correct.

Picking out of the estimate the items of cost that may be saved in whole, and apportioning those that may be saved in part by 60 feet lockage on each side of the mountain, the saving cannot be less than 350 000 000

francs, and probably much more. Most of the work under water, and other difficult portions would be avoided.

M. Dauzats stated the other night that the deep rock cut averages 180 feet deep for seven miles in length. By reducing the cut to 120 feet forty per cent. of the quantity would be saved, and considering the much greater cost per yard of taking out the bottom than the top, probably one-half the cost would be saved.

As the deep cut will doubtless take the longest time, it is probable that reducing the work in it one-half will reduce the time for completing the canal as much as one-quarter. The engineers say that "with good and judicious management the work can be completed in eight years," which means that it cannot be done in less. The locks would doubtless reduce this estimate to six years.

The locks should probably have 600 feet length and 80 feet width of chamber, with side pipes for filling and emptying 12 feet diameter, or what is very much better where the location permits, a large open channel on one side for filling, on the other for emptying. The prism of the canal should be enlarged above and below the lock so that the drawing of the water from the upper and discharging into the lower level should make no agitation of the water and no current near the lock.

This unnecessarily large size for present business adds but a very moderate percentage to the first cost, and almost nothing to the cost or time of operating. The waste of water in this case is of no account. Arrangements easy and inexpensive can be made beforehand for increasing the length without any interruption to the navigation, should that ever become necessary. My experience in lengthening locks has suggested how this can be done. The cost of six such locks, built in the best and safest manner, but without fancy masonry, may be seven or eight millions of dollars.

Unless a very great amount of property would be destroyed by the dam, to which our attention was called by Mr. Ward some time ago, it should be built as near the mouth of the Chagres River as a good site can be found, and raise the water from 20 to 80 feet, as the condition of property on the river above may permit. If the damages were $20 000-000, or even much more than that, there would still be an immense gain by it. It would make a safer and quicker navigation than a sea-level canal. Instead of a narrow canal with only passing places every 3 or 4 miles, involving some hours detention to each vessel, and a constant risk

of scraping the bilge on the slopes of the banks, vessels could go through an open lake, in deep water, without risk or interruption, and at much higher speed, and it would save much difficult and expensive work, and form a reservoir for, and discharge gradually, an immense amount of flood water.

The dam should be of timber cribs filled with stone, sunk on any kind of bottom, with an apron below of crib work 5 feet or 6 feet deep, filled with stone, except near the lower end, covered with logs parallel to the stream, carried down stream 150 feet to keep the excavation made by the water in the bed of the stream at a safe distance from the dam. Such cribs, unless undermined, are immovable, and being always wet, indestructible. The logs on the lower side might require protection from the teredo. In my long experience I have seen almost every other kind of work give way, but never such dams.

A dam 100 feet base, 80 feet high, with apron 150 feet long, 6 feet deep, would probably cost $500 per foot lineal, or 2 000 feet long would cost a million. This is 50 per cent. more per cubic foot of dam than the prices I am accustomed to. There is no difficulty in raising the water 60 or 80 feet by such a dam. If its whole height is 120 feet and base 150 feet it would cost $1 300 per foot lineal.

I judge from M. de Lesseps' raised map that a good site may be found in the right place.

The saving by the 60 feet lockage on each side being 350 000 000 francs, deduct the cost of the locks and dam, and the probable damages, and we have a net saving in construction of 300.000 000 francs or $60 000 000.

If the time without locks is 8 years, and the cost $168 000 000, as estimated by the engineers, and if one-eighth of that sum = $21 000 000 is set apart at the beginning of each year, then at 7 per cent., compounded every 6 months (which is far less than the experience of this country warrants us in expecting, especially in an enteprise regarded as so doubtful as this), the interest up to the time of completion will be ($21 000 000 × 3.04 =) $63 840 000. If the time with locks is 6 years and the cost $108 000 000, the interest at the same rate to the time of completion is $(108\,000\,000 \times 1.686^{\frac{1}{6}}) - \$30\,348\,000$. The saving in interest by the locks is ($63 840 000 — 30 348 000) over $33 000 000. Add this to the $60 000 000 saved in construction, and we have over $93 000 000 saved in construction and interest up to the time of completion.

The cost per yard of the deep cut will be considerably reduced, in addition to other considerations, by giving more time to do the same quantities.

But there is a claim for deduction from this for the maintenance and operation of the locks and for the detention of vessels passing them.

The principal expense of maintaining locks is on the wickets in the gates. I would have none in this case, but feed and empty by channels on each side, or, where the locations do not permit that, large side pipes.

The largest calculation for cost of maintenance and of operating in the manner I propose, cannot exceed $50 000 per annum for each lock, making for the whole $300 000. As for accidents, there is less danger with suitable appliances for handling than on any other 1 000 feet in length of the canal ; for the vessel is under stronger, more perfect, and more expert handling than anywhere else.

The detention, as shown hereafter, need not be more than half an hour at each lock, or three hours in all. With ordinary vessels it would be much less. The present California ships carry 3 000 or 4 000 tons measurement, or about 2 200 tons actual weight. Taking all ships, great and small, they will probably average at least 2 500 tons weight, or 4 000 tons measurement.. If 6 000 000 tons measurement passes the canal per annum it will then require 1 500 vessels ; if 6 000 000 weight, 2 400. But I can afford to admit for this purpose that there will be 10 000 000 tons in weight per annum in 4 000 vessels, and that the detention involves a loss of $15 per hour. Then the whole loss from detention is $180 000 per annum.

Add these two sums and we have as an outside calculation $480 000 per annum against the locks. At 7 per cent. this represents a capital of a little less than $7 000 000 ; at 6, $8 000 000 ; at 5, $9 600 000. I can afford to call it $10 000 000.

Deducting this from $93 000 000 we have $83 000 000 net saving. The estimate for a sea-level canal being $168 000 000, and the interest during construction nearly $64 000 000 (and both will be greatly exceeded), the whole cost up to the time of completion is $232 000 000.

The $83 000 000 net saving, after deducting all disadvantages, is considerably more than one-third of the whole estimate.

If so much can be saved with so little loss, by 60 feet lockage on each side, why not have more lockage ? I cannot answer, without knowing

whether the water can be always at command so high up ; and not knowing the ground, how expensive the feeder might be to reach the summit. There will doubtless be abundant water at all times in the pool above the great dam at the height of 60 feet above tide, perhaps much more.

As I have already said, if animal power was to be used in hauling large vessels into and out of the locks, or if they were moved only by their own engines, or if the gates and valves were operated by human hands, all of which is, as I suppose, still the practice in every canal in the world but one, I should agree with M. de Lesseps that for a canal navigated by large ships, locks should be avoided whatever the cost might be.

It is under such experience that the present public opinion against locks was formed. We have all seen the slow and sometimes dangerous operation of getting a big ship into her berth or dock. Though in the case of a canal lock there is no tide across the ship's course, the delay and risk with the ordinary mode of handling are so great as to be avoided at any cost.

In my younger days I had charge of the Delaware & Raritan Canal, which connects the waters of New York and Philadelphia. The locks have 24 feet width and 220 feet length of chamber. They were calculated to pass vessels of nearly that length, but terminal and connectional considerations prevented the general adoption of such long vessels. The locks commonly pass two boats of about half their length, often having an aggregate weight of a million and a quarter to a million and a half of pounds. I was so much impressed with the slowness and risk of handling these heavy vessels and operating the locks in the old way, and their consequent low limit of capacity, that for many years I had it in contemplation to use steam upon the walls to haul the vessels in and out and open and shut the gates and valves. In 1868 the canal nearly reached its capacity with the then arrangements, and in that year and the next I carried out my long contemplated plan. The capacity of the canal was increased 50 per cent., and accidents previously not uncommon are unheard of since. As this was early a pet plan of mine, I have watched it ever since. I was surprised in 1869 to find no such contrivance for hauling vessels at any of the London or Liverpool docks, though they had hydraulic power on the spot. I learn that some such contrivance has come into use there since.

The whole apparatus is very simple. The engine has two small cyl-

inders, working cranks at right angles on the same shaft. This gearing down through some intermediate wheels works a drum 3 inches in diameter, which moves a one-inch wire hauling cable, along the face of the lock wall, after passing around sheaves above and below the lock. The speed of the rope is half that of the pistons. This hauling cable is connected with the vessel by a rope fastened at one end to a ring in the cable, and at the other to a timber head on the vessel. The cables were made by Roebling and have never broken. The engines and machinery were made by Mr. Wm. Cowin, at the Lambertville Iron Works. The engineer stands on a sheltered projecting platform over the edge of the lock, some 8 or 10 feet above the top of the wall, and has all the levers for every operation in reach without moving from his position, or turning his face away from the vessel. Though he has so many pullings and haulings and openings and shuttings, they are not simultaneous, but in succession. The whole operation is thus performed by a single expert, trained to this work—sheltered from the weather, instead of inferior and inexperienced men, whether on the vessel or on the walls, sometimes exposed to the storm and often failing to act in concert.

I shall not describe the apparatus now used in detail, but state what I think should be used in the proposed Isthmian Canal.

Suppose a ship may possibly pass equal in weight to a rectangular box 48 feet wide 500 feet long, with immersed depth of 25 feet ; equal to an actual ship of 48 feet beam, over 600 feet long, drawing 26 or 28 feet. The displacement of such a box would be 600 000 cubic feet, and if in fresh water, the weight would be 37 500 000 pounds. To make the case still more extreme, call it 40 000 000 pounds.

To overcome the inertia of this mass and give it a velocity of 2 feet per second in 60 seconds, or to stop that velocity in 60 seconds (disregarding the resistance of the water), the acceleration or retardation must be $\frac{2}{60} = \frac{1}{30} = 0.033$ feet per second. As the whole weight gives an acceleration of 32 feet per second, it requires $\left(\frac{W}{30} = 32\ p\ .\therefore\ p = \frac{1}{960}\ W = \right)$ 41 666 pounds, to give such ship a velocity of 2 feet in one minute. This requires an iron wire rope 2½ inches in diameter to transmit the power. A steel rope may be smaller. As the movement is so slow and these extreme weights seldom moved, and with the contrivance hereafter mentioned, the rope need not be so large as if running rapidly and constantly.

The power may be generated by an engine of two cylinders each 16 or 18 inches diameter, the pistons ordinarily moving 240 feet per minute. This power should be used in succession to haul the vessels in and out; to haul and hold the four breast lines; to open and shut the main gates; to open and shut the valves that admit and discharge the water to fill and empty the lock; to operate the brake hereafter mentioned; to handle the light shears used to pass shore lines on board a vessel, not yet otherwise in reach; to lift out and replace gates and valves when necessary, and to raise the guard gate hereafter mentioned when necessary.

An iron pipe 2 feet in diameter must be placed under the bottom of the upper level, on the upper side of the head wall, through which the wire ropes pass that carry the power from the engine to the other side of the lock.

The part of the hauling cable that moves along the face of the lock and never reaches the drum, should be 4 inches in diameter, covered so as not to be injured by friction, and a friction brake worked by the engine should be ready to be applied to it near each end of the lock. If it is ever necessary to use this brake it will stop 40 000 000 pounds moving 2 feet per second, in 15 seconds; moving in that time 15 feet, and the strain is, $= \frac{W}{32 \times \frac{2}{15}} = 166\ 666$ pounds. A snubbing line of the same size should pass from a ring in the cable to the quarter of the ship, in stormy weather.

Breast lines, one on each bow of the ship, and one on each quarter, should be used to hold the ship firmly in her course while going into and out of the lock and in her position while the lock is filling and emptying. These should probably be 2½-inch wire ropes, hauled and held by the engine. Several plans suggest themselves, simple and sure in their operation, of traveling apparatus running in grooves, and moved by the engine, for carrying along these lines on shore.

Each ship on approaching the canal should be provided with strong lines with a ring or hook at one end to project through the hawse holes or over the bulwarks, the other end made fast to the bitts or something else. To these rings or hooks corresponding hooks or rings on the breast and hauling lines handed aboard by the shears can be attached without delay. These lines may be given up on leaving the canal. Large ships should not be allowed to touch the gates or walls, and it is easy to prevent them.

There should be a strongly trussed guard gate working on a horizontal hollow quoin, lying under the water at the head of the lock, which can be raised in a few seconds by the engine. I have found such of great use.

Steamers may, perhaps, sometimes go out by their own power, but not in. They have not such quick and delicate control of their power. Everything should be done by the one expert, always in his sheltered commanding position. Though he has so many things to do, he does only one at a time.

The lock when technically "empty," should have four feet water under the bottom of the deepest vessels, so that they can move easily, and not surge when the water comes in rapidly in filling.

To guard against the possibility of detention in case of accident to the gates, spare gates should be kept on hand. Shears should be always ready for use on the side where the engine is, opposite to each pair of gates, and then the engines can take out the old and put in the new gate without an hour's detention. Some of these precautions are against difficulties that will seldom or never occur.

It may be said that all this requires much watching, that the machinery may get out of order, and that it is expensive. In fact, every part of the machinery is of the simplest kind ; the experience of 11 years is that it does not get out of order. I never heard of an accident or failure. As to cost, it is well worth while to spend thousands in order to save millions.

It may be said that we cannot reason from handling 1 500 000 pounds up to 40 000 000. The difference is, that in the latter case the power must be greater, the apparatus stronger, the motions slower, and even the slightest concussion must be (as it can be) absolutely prevented.

When we see a steel converter handled with so much facility and six tons of melted metal poured out with as much ease and certainty as a lady pours out a cup of tea, we need not be surprised that a ship, however large, can by the same powerful agency and proper appliances, be handled as easily and safely.

Hydraulic engines would be better than the direct application of steam, but more expensive.

Before putting up my lock operators 11 years ago, I calculated every resistance—strain, power and motion. After years of trial I do not think of a single thing I would alter. Nothing has failed or broken, and times

have not varied a quarter of a minute from the calculations. I, therefore, feel warranted in speaking on the subject with the utmost confidence.

The time required to pass the heaviest vessel will be about as follows:

Attaching the ship to the hauling cable, and attaching breast line fore and aft and on each side	1	minute.
Getting up motion of two feet per second and going sixty feet	1	"
Moving 840 feet at 2 feet per second	7	"
Stopping in sixty seconds	1	"
Securing vessel and shutting gates at the same time	2	"
Filling lock 6 minutes, (emptying 5)	6	"
Getting up speed, as before	1	"
Hauling out, if up stream 6, down 8; average	7	"
	26	"

Allow 4 minutes for slowing up, &c., before reaching the lock, and we have half an hour.

With 12 feet feeding and emptying pipes on each side, the lock can be filled or emptied in 5 minutes; with open channels on each side of the lock, much sooner. A lock on the upper Lehigh, 27½ feet lift, was emptied in a minute and a half. But it may not be always prudent to fill under 6 minutes. The valves are under such absolute control of the engineer, who watches the effects, that he can fill as gently or as rapidly as circumstances require.

Smaller vessels can be safely passed much more rapidly.

On the Delaware & Raritan two loaded boats may be passed one way, and two light boats the other, in 16 minutes—the loaded in 9, the light in 7. It is commonly done in 18 minutes. The locks are filled or emptied in 2 minutes.

Pumps to be worked by the engine should be on hand to give access to all the works under water, for inspection or repairs.

If single locks should become insufficient in 20 years, or longer locks be required, the present value of the cost of building them at that time, is only one-fourth of that cost. It is as economical to pay 4 dollars 20 years hence, for a thing you don't want till then, as to pay one dollar for it now.

To slackwater the Chagres and build a half dozen locks would make a navigation safer and speedier than a sea-level canal. The speed could be higher in the open river, or rather lake; vessels would not have to lie still, perhaps nearly half the time at the passing places, and they would have less chance of having their copper scraped off against the slopes of the banks. If the canal were made without locks, the best thing to be done would be at once to put in one at each end, so as to deepen and widen the canal, make the safe speed higher, and enable vessels to pass each other almost anywhere. The danger at locks can be made less than on any other part of the canal.

Canal engineering and canal management are still running in the grooves established in the age of Louis the Fourteenth. The few canals now made are not such as require skill, but main strength and money. The improvements that have been made are unknown to the great world, because the world in these *uncanalling* days has taken no interest in the subject. Little about them has got into the books, for it was useless to put there what nobody would read.

Hence an uninformed public opinion objects to locks for large ships, because such ships have heretofore been handled at wharves and docks by hand, or without such apparatus as can easily be applied at a lock built with a view to such application. I would no more think of passing a ship through a lock, or holding it in its place by animal power, than of rowing it by hand across the Atlantic.

"An artificial strait:" "A watercourse without impediment," and all such phrases have a magnificent ring, but to spend eighty or a hundred millions of dollars for an idea —to satisfy an unreasoning or uninformed public opinion, is bad engineering. That is the best engineering, not which makes the most splendid, or even the most perfect work, but that which makes a work that answers the purpose well, at the least cost. The demand of the public for a canal without locks, reminds one of Charles Lamb's youthful Chinaman, who for want of knowing any cheaper way, burned down his house to roast his pig.

A canal is not a monument, but an enterprise. No engineer is warranted in building a monument to himself with other people's money. Besides a splendid work, more expensive than is necessary to answer the purpose, is a monument that confers no credit on the builder. To make an enormously expensive work, when a cheaper one skillfully made and operated, would answer the purpose even better, is at best a magnificent

mistake, just what Stephenson said his Victoria bridge would be, if Roebling's Niagara bridge succeeded.

M. de Lesseps, by presenting his plans to this Society, has invited criticism. It is our duty to give it fearlessly ; and it is our duty when we are sure, from our own experience, that public opinion on engineering questions is mistaken on any point, to endeavor to set it right

To admit, that with all the powers and appliances now at our command, we cannot produce apparatus that will handle the largest vessel that ever floated, or that ever will float on the ocean, with the same facility, certainty and safety, that a steel converter is handled, is a disgrace to the engineering of this, the eve of the twentieth century.

Discussion by William E. Merrill.

I have read with great interest the discussion, in the January number, of Transactions of Inter-Oceanic Canal Projects, especially the paper by Mr. Evans. I would like to make a few remarks or points suggested by his discussion.

Like him, I have had a great deal to do with locks and dams, and like him I am afraid of them. In the Valley of the Ohio we have many rivers that are locked and dammed, all of which have a record of more or less disaster; and we have several, as the Kentucky, the Wabash, the Guyandotte, which once were locked and dammed and are so no longer, having succumbed to time and flood.

I agree with Mr. Evans that 1½ hours a lock is not too much for a first-class ocean steamer. I had an experience at the New York wharves with the *Celtic*, similar to the one which he had with her sister ship the *Britannic*. I have also seen large steamers enter the Birkenhead docks and I have passed through the locks of the Louisville and Portland Canal. From all of these I feel sure that 20 minutes to a lock is absurdly low. DeLagrené (*Navigation Interieure*) gives 23 minutes as the time for a tow-boat and its barges to pass through a lock on the Upper Seine, assuming that she is not detained above or below the lock. He says that a single barge without tow-boat requires 30 minutes.

Discussion by Charles Macdonald.

When, at our last meeting, an enquiring member asked how it was proposed to provide for the Obispo, an affluent of the Chagres, which empties into it from the north, Mr. Dirks at once answered that, although

the stream was a small one, and could, without detriment, be allowed to enter the canal, yet, if upon further consideration it was deemed best to keep it out, it could be swung over the canal on a drawbridge carrying a trough; and when the passage of vessels necessitated the opening of the bridge, the waters could be dammed back by sluice-gates.

This original and ingenious suggestion affords a tempting inducement to an engineer like myself, whose experience has been more in the direction of bridges than canals, to join in the discussion of a subject which has became of such national importance, swinging into it as it were from the nethermost side, and quite willing to be dammed back, if need be, to make way for the unobstructed flow of more matured opinions.

We have had full discussion of the relative merits and demerits of the different routes proposed and of their probable cost, not only by those who have local interests at stake, and who may therefore be assumed to be more or less prejudiced, but by old and experienced hydraulic engineers, who could only be influenced in their conclusions by a sense of unbiased truthfulness, and an exalted estimate of the value to be attached to a professional opinion. Hence it may be assumed that those of us who have no personal knowledge of the difficulty of the problem to be solved, who have not been deprived of rest by anticipation of "earthquakes on the line of the San Juan," or consigned to a period of inaction under the depressing influences of that wonderfully varying "belt of calms" encircling the Bay of Panama; those of us, in fact, who must take our information second hand, may nevertheless have arrived at a reasonably clear idea of what is involved in the construction of a canal across the American Isthmus.

Thanks to the courtesy of that enlightened engineer, M. de Garay, we have been pretty fully informed of the workings of that professional gathering at Paris, which, under the guidance of a master hand, was enabled to reach conclusions with such remarkable celerity and apparent unanimity.

It is true, that body did not look with favorable eye upon the Tehuantepec route, involving, as it does, an overland trip through Mexico; but I am sure many of us who had the pleasure of listening to his eloquent exposition of the advantages of that route, will agree with him that if inter-oceanic communication can be successfully accomplished by means of a canal *with locks*, the precise amount of elevation to be overcome is not by any means the most important thing to be considered.

particularly when there are such potent geographical arguments in favor of a more northern route.

Mr. Menocal's paper on the Nicaragua route has been so fully discussed by members whose experience in canal construction enables them to speak with authority, that it would seem to be unnecessary to add to what has been said in order to illustrate more fully the utter inadequacy of the plan to the requirements of the case. A canal which would not accommodate vessels of the dimensions which are found to be the most economical at the present time, can scarcely be entitled to serious consideration so long as there is a possibility of obtaining an unobstructed water-way at the sea level, and upon a much shorter route. As regards the first cost of a canal with locks *via* Nicaragua compared with that of a sea-level canal, it seems to me that Mr. Menocal has seriously underestimated the difficulties to be overcome upon the route favored by him, both as regards quantities to be removed and cost per yard, to say nothing of the greatly increased dimensions which would undoubtedly be insisted upon if the work were ever undertaken, and the never-ending sources of expense attending the working of locks, certainly not less than 600 feet long by 60 feet wide. The question of first cost must undoubtedly receive due consideration, but Mr. Menocal's figures, for a canal at Nicaragua do not rise even to the dignity of a rough approximation, as Mr. Evans has clearly shown, and they may with propriety be consigned to the seclusion of a convenient pigeon-hole until such time as a sea-level canal is proved to be impracticable.

The San Blas route, located as it is upon the shortest line across the Isthmus and with good harbors at either end, would from these circumstances alone be very likely to attract favorable notice.

That it has not been as carefully surveyed as some of the other lines is certainly not the fault of Mr. Kelley, who, after having spent much time and money in a purely disinterested effort to fathom the mystery of the Isthmus, has finally arrived at the conclusion that, notwithstanding the colossal difficulties involved in the construction of a tunnel at least seven miles long, and big enough to pass the ships of the future, the route by way of San Blas is the best. In this he is supported by no less eminent an engineer than W. W. Evans, who is specially qualified to speak with authority upon such subjects.

But even if it be granted that the physical difficulties can be overcome at anything like the figures named by Mr. Kelley, there will yet remain

the commercial question, Can owners of ships be induced to risk them seven miles underground ?

I confess to being somewhat skeptical on this point, without being able to give a scientific reason for my belief, or rather unbelief. Certain it is, that unless a structure presents the *appearance* of safety to the lay mind, it is very difficult to beget confidence in it ; and I do not think it requires any argument to prove that the *fear* of possible accident from falling rock in a tunnel 150 feet high and of such exceptional length would deflect a large proportion of the tonnage which might otherwise be counted upon.

Whatever may be said in criticism of the methods employed at the Paris Congress, it is beginning to be admitted, perhaps in undertones as yet, but nevertheless with growing force, that the decisions arrived at, so far as they related to engineering questions, were founded upon sound principles, and unless some new developments take place outside the range of professional investigation, they must eventually be accepted as conclusive in determining the direction of active effort in the solution of this great problem.

M. de Lesseps, whether he be called diplomat or engineer, has undoubtedly proved himself to be possessed of a genius for affairs which is satisfied with nothing short of a comprehensive and complete accomplishment of whatever he undertakes ; and in the treatment of this question, I believe he has arrived at the only conclusion which will stand the test of vigorous investigation ; and that a sea-level canal at Panama is not only physically practicable, but it is the only expedient by which the commerce of the world can be *permanently* and *materially* benefited, so far as isthmian communication is concerned.

The cost of such a canal has been estimated by engineers whose experience in similar work eminently qualifies them for such duty ; and when we are assured by Herr Dirks that he is willing to stake his reputation on the possibility of constructing the canal at Panama for a total sum of $168 000 000, we cannot but assume that the probabilities are in favor of the accuracy of the figures given.

But there are two features of this question which lie outside of and beyond the exclusive domain of the engineer, although engineers may refer to them as possibly of sufficient importance to overshadow the professional difficulties altogether. I allude to the contingent expenses attending the raising of the money to carry out the work ; and to the revenue to be expected.

First, as to contingent expenses :

It is scarcely necessary to remark that the contingencies attending a work of this magnitude are likely to be very great, and quite as complicated in their estimation as the determination of the revenue.

The Suez Company was organized with a capital of $40 000 000 in 1858, but the capital account on the completion of the work was $91 500 000, or more than double the original capital stock.

If we apply a similar ratio to the Panama scheme, with an original capital of $120 000 000, as proposed by M. de Lesseps, we should expect to find the final cost reach the neighborhood of $300 000 000 ; and I am inclined to think that the figures will exceed, rather than fall within, this limit. But as engineers, we would certainly not be accepted as a competent tribunal of last resort in matters pertaining to contingencies ; and it is for this reason that we may, with propriety, leave the further development of the issue in the hands of such an one as M. de Lesseps, whose experience in other and more varied spheres of action justly entitle him to command the respectful attention of capitalists, and the glowing admiration of the engineer.

Now, as to revenue : The Committee on Statistics, at the Paris Congress, estimated the canal tonnage as follows :

From and to the United States	2 000 000 tons.
" " " England	1 500 000 "
" " " France	356 000 "
" " " other countries	356 000 "
New traffic, Europe to the Orient	1 333 000 "
Estimated present tonnage	5 095 000 "

But, as it was assumed that the canal would take 10 years in building, and that during that time traffic would increase at the rate of 5 per cent. a year, it was stated that the total tonnage between the Atlantic and Pacific upon the opening of the canal might be expected to amount to 7 250 000 tons annually.

It was not claimed, however, that the whole of this would pass through the canal. Indeed, the Committee uttered a distinct note of warning against the assumption that either in the first year, or in subsequent years, this amount of tonnage could be relied upon to pass the canal. It was stated to be as the total volume, the reservoir from which

traffic was to be drawn, and how much of it would go by other routes, or how much through the canal, would depend on trade considerations which the Committee did not feel warranted in assuming.

From which it will appear that the estimated revenue of $18 000 000 upon an assumed tonnage of 6 000 000 tons is based upon extremely imperfect information.

It is understood that the Bureau of Statistics, at Washington, has been compiling some statements upon this subject for several months, but has not yet arrived at definite results. We are promised copies of them when completed, and it is not impossible that they may show that to some extent the Paris Congress, for want of better knowledge, was compelled to draw upon its imagination for its facts.

The only precedent we have upon which to base assumption is the experience at Suez, where we find a canal connecting inland waters, teeming with an immense local traffic, so to speak, and most favorably situated for facilitating the intercourse between 200 000 000 of people in India and the governing country, England; and yet the tonnage at Suez does not much exceed 3 000 000 of tons per annum, the exact figures from the date of opening being

Year.	Ships.	French Tons.
1870.....	486.....	654 915
1871.....	765.....	1 142 200
1872.....	1 082.....	1 744 481
1873.....	1 173.....	2 085 072
1874.....	1 264.....	2 423 672
1875.....	1 494.....	2 940 708
1876.....	1 457.....	3 072 107
1877.....	1 663.....	3 418 949
1878.....	1 593.....	3 291 535

If we contrast the geographical conditions at Suez and Panama, the comparison would be very much as if we were to take the business on the New York Central & Hudson River Railroad as a guide in estimating a probable traffic of the Northern Pacific Railroad—the one a trunk line passing through a rich and thickly settled country, and the other a pioneer of civilization, pushing out into the trackless prairie, drawing with it a tide of emigration, and opening new and unexpected sources of wealth; yet from this very comparison we may, perhaps, be the

better able to judge of the commercial prospects of the Panama canal, while it is more than probable that if that canal were opened to-day from the Atlantic to the Pacific, there would not be a tithe of the estimated traffic ready to make use of it. Nevertheless, we are to bear in mind that in the ten years which must ensue before it can be built great developments in trade and commerce are to be expected, and particularly will this be the case with our own coasting trade between the Atlantic and Pacific States.

Who shall say what the amount of that increase may be? Who, that is at all familiar with the development of the Great West, will pretend to forecast the commercial balance-sheet for the year 1890? May we not assume, therefore, that as regards revenue, there will be wide differences of opinion? And inasmuch as the capital necessary for the construction of such a work would be obtained, if at all, from sources outside the range of engineering influences, it will be quite unnecessary for us to discuss this branch of the subject further.

Discussion by Ashbel Welch.

I understand my friend who has just sat down to indorse the sea-level plan of M. de Lesseps for a ship canal from ocean to ocean through the Valley of the Chagres, rather than a canal with locks, on the ground of the great cost of construction, maintenance and operation of locks, the great delay in passing them, and the risk of injury to the vessels while passing.

To avoid the locks, M. de Lesseps proposes to build a narrow, far underground, enormously expensive canal, too narrow for large ships to pass, except at passing places averaging 5 miles apart, sunk under the bottom of a valley sometimes flooded 45 or 50 feet deep, with artificial rivers hanging over it along the hill sides to divert the flood water, which are always liable to burst their banks, with the most disastrous consequences to the canal and everything in it.

The first thought of an American canal and river engineer, on looking at M. de Lesseps' raised map, is to convert the valley of the lower Chagres into an artificial lake, some 20 miles long, by a dam across the valley at or near the point where the proposed canal strikes it a few miles from Colon, such as was advocated by Mr. C. D. Ward.

To avoid the expensive, dangerous, and tedious canal proposed by

M. de Lesseps, I would make such an artificial lake ; its surface, say 80 feet or more higher than the ocean, which, if M. de Lesseps' raised map is at all correct, would give a ship channel 40 or 50 feet deep, and more than a quarter of a mile wide in the narrowest place. I hear the objection that the Chagres is a crooked stream, and could not be navigated by long ships. That is quite true. Of course, I would not merely slack-water the *river*. But the *valley* is direct, without sharp turns, and the ship channel would occupy the whole of that valley, not the mere bed of the stream that meanders through it.

To make this lake 80 feet high and reach it, would require a dam which might be 120 feet high from the bottom of the mud of the Chagres for a few hundred feet in length of dam, and which should reach from rock to rock, and 4 locks averaging 20 feet lift each.

A crib dam 200 feet base, 120 feet high from the bottom of the mud of the river, with crib apron averaging 15 feet deep and extending 300 feet down stream, from the dam proper, would cost in a wooded country here, including filling all cribs with stone and gravelling on the upper side of the dam, from $1 500 to $2 000 per foot lineal.

On the Isthmus it might cost $3 000 per foot lineal. If the Chagres is 1 000 feet wide, this makes $300 000. If the distances to the high land on each side are 2 000 feet, the cost per foot lineal for a rubble masonry dam, with the gravelling above it, may be $400 per foot lineal, making $1 600 000. Total, under $2 000 000. For the present purpose we will double this and call it $4 000 000.

Mr. Evans, in his very able paper advocating the San Blas route in preference to the Chagres valley, speaks of dams as hazardous, and of the destruction by a great flood of the dams on the upper Lehigh. These crib dams proper were not injured by the flood. The water overflowed, and in consequence carried away the embankments between the ends of the dams and the highlands, and carried away almost everything else but the crib dams themselves, which stood unharmed in the midst of the torrent.

It would also require to get up to the lake thus formed, four locks averaging 20 feet lift each. These locks, say 600 feet by 80 feet chamber, with high level basin on one side, and outlet channel on the other, with 10 openings, 6 feet by 10 feet through each wall, to fill and empty in 2¼ or 2½ minutes, when there is nothing in the lock, or with a ship in the lock to fill safely in 6 minutes and empty in 4 minutes, and steam

engine on the wall, and the appliances to open and shut all the gates and valves, and haul and handle the ships by steam, would cost from a million and a quarter to a million and a half of dollars. The maintenance of the locks would be very little, the things that cause nearly all the expense of maintaining ordinary locks being avoided. The operating including the maintenance of machinery and manning the locks might reach $50 000 each per annum. Roughly, we may say that the cost of the lock and operating apparatus, and the sum of which the annual expense of maintenance and operation equals the interest, is two millions of dollars for such a lock, or one hundred thousand dollars per foot lift. The 4 locks to get up from the Atlantic to the lake, and the four to get down into the Pacific, would cost for construction, maintenance and operation equivalent to a capital of $16 000 000.

This would require the re-location of the Panama Railroad for some 20 miles on a higher level. An outside calculation for this would be $250 000 a mile, making $5 000 000.

Some villages of native huts, and some banana patches, would be overflowed. This could not be worth many millions, if even one. But if it would cost twenty millions for damages, it would be money saved to pay it.

The locks, dam, and damages, might cost, including the principal, of which annual expense is the interest, thirty millions of dollars.

M. de Lesseps estimates the cost of his canal at $168 000 000. Most canals that I ever knew, or knew about, have cost very much more than the estimate. They cannot be estimated as railroads can, there are so many uncertain and unforeseen items, especially the very heavy item of pumping, and others arising from the work being so low down in, or under the bottoms of the valleys. The Suez Canal, I understood, cost double the estimate. I should add 50 per cent. to the estimate named, making it $250 000 000.

The locks and dam would save nearly all the artificial canal, some of it through rock, cut for 20 miles along the Chagres ; it would diminish the average deep cut 7 miles long, from 180 feet to 100 feet deep, and decrease the cost of the rest of the work a good deal. I suppose it will hardly be questioned that the cost on the plan I propose would be 40 per cent. less than the thorough cut, that is, $150 000 000. I would not, in any case, dispense with the dam and reservoir to hold back the storm waters of the upper Chagres.

If the canal costs $250 000 000, and takes 10 years to complete, and one-tenth of the cost is set apart at the beginning of each year, then the interest at 7 per cent. compounded every six months, will be over $122 000 000 up to the time of completion. This makes $372 000 000.

If the canal costs $150 000 000, and it takes seven and a half years to finish it, and $20 000 000 are appropriated at the beginning of each year, then at the same rate, the interest up to the time of completion, is a little over $46 000 000. Add this to the principal, and we have $196,000 000; the difference is $176 000 000. Roughly, the cost by the latter plan would be one-half as much by this as by the other plan.

The first objection to locks is the great cost of their construction, maintenance and operation. The cost of maintenance of a ship lock itself, properly constructed, is very little. The great cost of construction and operation is freely admitted. Twenty million of dollars is a great deal of money, but if you can save a hundred millions by spending twenty, then it is economy to spend it.

The particular point that I wish to make is, that the canal, with the lake and the locks would not only be cheaper than the thorough cut, but far better when done ; and that too in the very particulars in which it is objected to ; the speed and safety of the vessels, and the safety of the canal itself.

I understand the calculation to be that vessels while moving through M. de Lesseps' canal can go three miles an hour, and that the detentions at the passing places for large vessels will be at least fifteen hours. This makes the whole time 30 hours.

In the lake, large ships and steamers can probably go 5 to 10 miles an hour, more easily than they can go 3 in the canal. This makes 2, or at most, 4 hours. To pass through the 8 locks we must allow 4 hours more, The rest of the canal, 25 miles, requires at the same rate as in the thorough cut, about 17. The sum of these is 23 to 25 hours, against 30 by the sea-level canal.

As M. de Lesseps says it takes an hour and a half for a ship to pass a lock ; it is proper that I should explain how it can be done in less than a third of that time.

I here repeat what I said on a former occasion, that I would no more think of making a ship canal, with locks to be worked by hand, or of hauling and handling the ships there by human or quadruped power, or by their own steam afloat, than I would think of rowing a ship by hand

across the Atlantic. A puff of wind would give them a motion which could not be controlled. The steam afloat acting against unstable water, is too uncertain and too slow to change, and therefore, unsafe. If I knew of no other way of operating locks and handling vessels at them, then I should agree with him that locks should be avoided at whatever cost, and at whatever other sacrifice.

The decision of so many eminent and able engineers in favor of a scheme so very objectionable in so many respects as this sea-level canal, is evidently owing to not considering that there is an agent at command sufficiently powerful not only to operate the largest lock ever dreamed of, but to move, handle and hold the largest ship that ever floated, and that with appliances of the simplest kind, and quick and certain in their operation. Of course, I mean steam, not afloat, but on the lock wall, where it has a fixed base of operation. All the processes are performed by a single expert, who, from his elevated and sheltered position, does everything, and has every lever within reach without changing his position or turning his head.

This is not a mere theory or untried project, but I devised it many years ago, and put it in operation eleven years ago, and it has been in successful operation ever since. True, it is on a much smaller scale; but on the other hand, it is not on locks best adapted to the purpose, which a ship canal lock can and should be, and the apparatus is so simple that it can be applied with ease and certainty on any scale.

The steam "lock-operator," as I have christened it, removes all the objection to locks, except the cost of construction and of operation; and it is a question in each case that arises whether more than that cost is saved in some other way; and it is a question in each case whether more time is saved in some other way than is lost by the locks.

Large ships, passing a lock, should be held firmly in every direction, and never allowed to touch the walls or gates. They should be hauled in slowly ; out as rapidly as the stationary power will move them. Their own steam should not be used except, perhaps, in going out, and their rudders should not be relied on, nor their own crews, except merely to hook on the wire rope lines.

I shall not describe the apparatus now, having, on a former occasion, pointed out generally its mode of operation, and intending, with the indulgence of this Society, to submit to them, on a future occasion, what I think the proper plan for a ship canal lock and its "lock-operator."

M. de Lesseps, and others, infer that it is a long and ticklish operation to pass a ship through a lock, because it is so to get it into a dock or berth from an open river or bay. But the circumstances are very different. In the canal, the ship heads right to enter the lock from the first; in getting into her berth, from the river, she must commonly change her direction 90 degrees. In the canal there is no cross current, as often in getting into docks, and there need be and should be no current at all. In the canal, there is something fixed on each side to fasten to and pull from in every direction, which commonly there is not in getting into docks.

Though not myself in charge of them, I have long watched the handling of ships, and I once had much experience in handling vessels a great deal too large to be moved, without delay and danger, by animal power. I know from experience, not only the very great saving of time, but the immunity from accident, resulting from the adoption of the stationary steam apparatus. A ship passing a lock properly constructed and so provided, ought to be quite as safe as in any other part of the canal.

The very large and numerous gates by which I propose to admit and discharge the water through the sides of the lock, are, of course, intended to be opened and shut only by steam, and to hoist, not revolve.

The great risks to which the low-level canal must always be exposed and the greater safety of the lake is, perhaps, even a stronger argument in its favor than the saving in cost of construction.

It is proposed to intercept and divert the flood waters of the many streams that pour into the valley of the lower Chagres, by artificial rivers along the sides of the valley. A very little experience with such, must impress any one with the great danger of their bursting their banks, unless made in a manner and of dimensions enormously expensive, and evidently not contemplated in this case. Rivers, at any rate American rivers, are always doing something they never did before, and that nobody ever expected they ever would do. This very Chagres is said to have risen fifteen feet higher last November than in any of the tremendous floods ever previously known, thus discharging 50 or 100 per cent. more water per second than ever before known. The Delaware, which always had the reputation of a well-behaved river, rose to a very extraordinary height in October, 1787, during, what tradition calls, the "Pumpkin Fresh." In 1841 there came a flood that rose so much higher than the pumpkin fresh, as to discharge full 50 per cent. more water per second.

If the floods should break into the canal (as they surely will), they would not only fill it up, perhaps, for a long distance, and stop the navigation for a long time, but destroy the ships that might be caught in it. With such a current as would be created, any ship would be helpless, one end would fasten on one side, the other end on the other side, and on the subsidence of the water the ship must break in two or be ruinously strained. A large vessel is a very helpless thing in a small channel with a current. An effort was once made, within my knowledge, to navigate a canal feeder 60 feet wide on the surface, and 6 feet deep, with a current of only one foot per second, by schooners 80 feet or 90 feet long, 20 feet or 22 feet beam, drawing 5 feet water. In going with the current the bow often got fast against one bank, the stern against the other. On the Raritan, 30 miles from here, the steam tugs do not attempt to tow loaded vessels with the tide through the narrow part of the river. I have spent, in my younger days, many anxious hours in guarding against the irruption of high level waters into a canal, and many weary days and nights in repairing damages from them.

If the lake is formed, the great dam across the upper Chagres will still be necessary, and, doubtless, other dams to hold back the floods of some of the other rivers. But much of the storm water may be admitted without danger or inconvenience. To raise such a lake, an admissible height would take a great deal. Quite a current would be admissible in a channel so straight, broad and deep. But I am not prepared to say that even with the lake and dams the risk and inconvenience from the floods would be entirely overcome.

The large extent of the water-shed of the Chagres must be a very serious objection to a navigation through it upon any plan. I have never formed, much less expressed, an opinion which of all the proposed routes should be adopted, or whether the time has come to make any canal at all. I only insist that upon whatever route the canal is built, the best plan shall be adopted, and that an enormous amount shall not be expended to make a very imperfect and precarious navigation in order to avoid so slight a difficulty as half a dozen locks.

I confess to a prejudice in favor of the San Blas route. Perhaps it is partly from a prejudice in favor of its esteemed advocate, Mr. Kelley. The consideration that there are no floods to fear is one of immense importance. That it may be a sea-level canal is not its great merit. If there is water enough I would put in a lock or two at each end, so as to avoid

too deep a cut in earth, which is always troublesome. Most engineers know how expensive it often is to maintain even a railroad through a deep cut. I would make the canal in earth cuts, when not too expensive, 120 feet wide at bottom and 32 feet deep, so that vessels could go fast and safely and pass each other anywhere. The only question is not the cost, but the time it would take to make the seven-mile ship tunnel. As to the cost, it seems to me it is in this case fairly and fully estimated. But interest, after a few years, eats up your resources very fast.

There is one very serious error into which, perhaps, all the projectors have fallen. It shows how ideas on canal-making still run in the old groove. They all propose to make the bottom of the canal level, and within 2 feet of the bottom of the large ships. Such a ship, with only 2 feet water under her, can only be moved with great difficulty, and very slowly. Worse than that, a little inequality in the bottom, such as a sand bar a few inches high, will give a sheer, always liable to injure the vessel, against the bank. Even when such a ship has a speed of only two miles an hour, the counter flow and the lateral flow under her bottom has a high velocity. Any difference in the facility with which the lateral flow escapes gives the ship a sheer. The unequal current and the greater resistance, where the water is the shallowest, will more than counteract the guiding force of sides, keel and rudder. Probably, judging from my own observation in another canal, much of the difficulty in the Suez Canal arises from the inequalities in the bottom made by the dredging machines. The bottom should be dished so as to give 4 or 5 feet water under a large ship, being, of course, carried down full width, at least as deep as the bottom of the deeper ships. The speed could then be increased by the same power, the vessel would have steerage way, her tendency would be to keep the middle of the canal, and the commotion in the water tending to abrade the banks would be very much reduced.

If the soil of the Egypto-Arabian desert will hold the water, the best way would be to put in a lock at each end of the Suez Canal, pump up the water, or bring it from the Nile, if practicable, make the channel over 40 feet instead of under 30 feet deep, and wide enough to pass easily everywhere, and thus enable steamers to pass in 21 instead of 42 hours, as Mr. Evans found it took, and then they could sell the dredging machines.

In deep rock cuts a much better canal could be made at the same expense by making it deeper, even at the disadvantage of making it a

little narrower than proposed by most of the projectors. Take such a cut now proposed to be made, 100 feet deep, 100 feet wide at the water line, and slopes $\frac{1}{4}$ to 1, with 28 feet water. It would be a great improvement to make it 8 feet deeper at the centre line, so as to leave 36 feet water there, even if to keep the area of the cross-section the same the width at the water line had to be reduced to 94 feet or 95 feet. With the section, as commonly proposed, a ship, in the middle of the canal, 44 feet beam, drawing 26 feet water, would have 2 feet water under her bottom, and from 21 feet at the bilge to 28 feet at the water line on each side; with the section, as I propose, she would have 10 feet under her keel, and 18 to 25 feet on each side. In the former case she could not, in the latter she could, steer without difficulty. This is so obvious that it is strange it should escape anybody, and yet I confess I did not think of it till experience forced it on my attention.

From the foregoing considerations I am compelled to differ from my friend's conclusion, and believe that a very much better navigation than that proposed by M. de Lesseps can be built on the same route for much less money. To make a thorough cut canal through the valley of the Chagres would be to ignore the improvements of the Nineteenth Century.

Charles Macdonald.—In view of the fact that locks can be so readily utilized, how is it that the Tehuantepec route has not received more attention? It is true that there are about 750 feet elevation to be overcome, but it seems to me that we should have more light than we have had as to that route.

Ashbel Welch.—I do not know enough about the Tehuantepec route to express an opinion. That is a large amount of lockage to be overcome—750 feet. The first question is, have you got water enough? There are two difficulties in making canals—too little water, or too much water. The first question about the Tehuantepec route is, have you got water enough for the locks? I know nothing about it; but suppose you have water enough, then it is a question of cost and of delay. If, according to the calculation I have made—and I feel confident it is correct—taking into consideration the cost of construction and the cost of maintenance of the proposed locks, the money disadvantage of a lock is about one hundred thousand dollars per foot lift for such vessels as will pass through, and as should be provided for. I mean the first cost and the annual cost of operation capitalized. When I say that, I

do not mean locks of such lifts as are ordinarily made—eight or ten feet—I would have all the locks, when the location permits, at least 20 feet. If not too much embankment, I would go as high as 25 feet. I will not go higher, as at present advised, than 30 feet. I know of one such lock having been built and worked with perfect success, ease and safety and such a lock, within my knowledge, was filled and emptied in a minute and a half. There would be no difficulty in filling or emptying these in one and a half minutes. Filling in less than five minutes would not be proper when there is a vessel in the lock.

CHARLES MACDONALD.—There are about 550 feet of elevation more in the case of Tehuantepec than at Nicaragua, as I understand it.

ASHBEL WELCH.—That is if the Nicaragua Lake should be be raised three feet. It would be a great mistake to raise it only three feet, and then for several miles to sink the bed from ten feet down to nothing. Instead of doing that they ought to raise the surface of the lake twenty feet, and then they would have nothing to do at its bottom.

JOHN BOGART.—Mr. Adams says, in his discussion, that the summit of the Tehuantepec Canal, as projected, is 200 metres, or 656 feet, instead of 750 feet.

ASHBEL WELCH.—Double lockage gives 1 300 feet, that would cost $130 000 000 including the annual charge capitalized, provided the locks were such as I have spoken of.

CHARLES MACDONALD.—I thought that was only for the elevation—up and down. Does that include the whole canal?

ASHBEL WELCH.—For the lockage only. Locks are, of course, serious objections, if you can do without them. They are not necessarily fatal to this canal. You can calculate that it is a disadvantage of $100 000 to a foot lift. Now, for 1 300 feet lift, up and down, you can count the cost. Such locks as I propose, and such as ought to be built—for anything you build should be built to answer the purpose—would cost $130 000 000. I would sooner do that than make a canal below the bed of the Chagres River, with its deluges.

O. CHANUTE.—I would like to ask a question. I understood you to say that all vessels would be detained fifteen hours each in passing the Panama Canal, because they could not pass each other except at the passing places. Now, from the report of the Technical Commission, I see that the plan provides for a canal between Colon and kilometre 36 (the Atlantic Division), and between the 61st kilometre and Panama

(the Pacific Division), with a surface width of 50 metres—164 feet. Ordinary sailing vessels are only about 25 or 30 feet wide; steamers 40 feet; two such vessels should pass in these limits. Between kilometres 46 and 61 (the Summit Division), the canal width, at surface, is but 28 metres—about 92 feet. Here, perhaps, they could not pass each other; but there is no where else they could not do so.

ASHBEL WELCH.—It is true that small vessels could pass on the wider portions of the canal; but M. de Lesseps himself supposed that the vessels passing through the canal would be 520 feet long, and, I think, 48 feet beam. But in the wider portion of the canal, the bottom is not 90 feet wide.

O. CHANUTE.—The bottom is not.

ASHBEL WELCH.—The width of water at surface is not the point. The width at the bilge is. I do not think that they could pass two vessels of 48 feet beam.

O. CHANUTE.—They would not pass in a curve; but would they not pass on a straight line?

ASHBEL WELCH.—No, sir; they could not. They would scratch off the copper or paint.

CHARLES MACDONALD.—They may be made of steel.

ASHBEL WELCH.—They would scratch off the paint and injure the plates.

O. CHANUTE.—The dam, at the point it crosses the Chagres river, would be 80 feet high; would that lake in question, 20 miles up the stream, overflow the railroad?

ASHBEL WELCH.—It would overflow the railroad, requiring its relocation for twenty miles, costing, for aught I know, $250 000 per mile. I would say that was an extreme estimate. That would be five million dollars. As to the amount of damage to private property, I do not know. If it would save more than one hundred million dollars by the expenditure of twenty or thirty, it is a good bargain. There is not much private property to be destroyed.

JOHN C. CAMPBELL.—There are no considerable towns. The railroad company lease the land along the line of the road. A large quantity of bananas are raised there and exported to this country. I came home in a steamer a short time since and they had on board eighteen car loads of bananas, raised along the line of the road. But if the canal were built, the railroad would be of no use, and would have to be abandoned,

ASHBEL WELCH.—The money damage would only be the worth of the land, and there is no estimating the money value of that, or what the damage would be.

JOHN C. CAMPBELL.—It would not go up to twenty million dollars.

ASHBEL WELCH.—If you save one hundred million by investing twenty millions, you do well.

JOHN C. CAMPBELL.—You would save the whole by not doing anything.

Discussion by T. C. CLARKE.

I believe that a straight canal is better than a crooked one, that a short canal is better than a long one, and that a canal at sea level is better than one with many locks.

So far I believe M. de Lesseps is right, and if he can raise the three hundred millions of dollars necessary to build his Panama canal, I hope, for one, that he will succeed. At the same time I maintain that, looking at this question from the point of an investor, I should be very sorry to put any money in any canal which would cost over sixty millions of dollars.

My reasons are these: one of the most important questions is—what rate of tolls should be charged.

The rate proposed for the Panama canal, $3 00 per ton, measured upon a solid of the length, breadth, and depth of the vessel, is entirely too high. It is prohibitory for all sailing vessels, except those from New York, as the following figures will show.

Take the case of a guano vessel of 1 500 tons, from Callao to Liverpool. Her expenses, including insurance and interest on capital, I am informed, are about 80 dollars per day. The distance saved by a Panama canal would be about one-third of that via Cape Horn — 90 days by one, and 60 by the other—equal to 30 days. 30 days at $80, is $2 400 = $1 60 per ton. Three dollars per ton tolls would utterly exclude the 1 200 000 tons of vessels engaged in the guano and nitrate trades.

Take the case of a 1 500-ton ship, from San Francisco to Liverpool; the saving here would be as 9 to 16, or 120 days via Cape Horn, and 68 via canal, a saving of 52 days, $\times 80 = \$4\ 160$, or equal to about $2 53 per ton.

Vessels from New York to the west coast of America and to Asia

would save over $3 00 per ton. Steamers also, on account of their much greater expense per diem, could afford to pay $3 00 per ton.

The estimates of probable tonnage made by M. Lavasseur for the Paris Congress, are much too large.

He estimates 2 million tons from European ports to the East, which, I believe, would not pass through the canal at Panama, because the distances via Suez are so much less.

Liverpool to Melbourne	1 300 miles.
" to Yokohama	1 500 "
" to Hong Kong	4 500 "

—less by Suez than by Panama.

The effect of the trade winds would not overcome these differences for sailing vessels.

A canal at Panama, Nicaragua, or Tehuantepec would depend upon the trade between San Francisco and Europe, and the eastern ports of the United States, which for 1879 I find amounts to.... 568 738 tons.

Also for vessels engaged in the guano and nitrate trades, about	1 200 000 "
Tonnage of vessels in connection with Panama Railroad, about	450 000 "
And vessels from New York to west coast of America and to Asia, estimated average	781 262 "
	3 000 000 "

provided the tolls were not too high.

The expenses of repairs and maintenance of the canal, are hard to arrive at. An approximation, however, can be made from the reports of the Erie Canal, in which, before 1862, the total receipts from tolls were	$97 625 000
And the cost of repairs, maintenance, and attendance, but not enlargement, were	24 377 000

—or about 25 per cent.

If we add to this 10 per cent. for towage, and 5 per cent. for harbors and lighthouses, making 40 per cent., we shall not be far out of the way.

I estimate the probable net revenue of an inter-oceanic canal, based upon such tolls as the different trades could afford to pay, as follows :

Tons.			
570 000	San Francisco, Oregon, wheat, &c.	$2 00	$1 140 000
1 200 000	Peru and Chili, guano and nitrate	1 00	1 200 000
450 000	Steam, Panama	3 00	1 350 000
780 000	New York	3 00	2 340 000
3 000 000 tons average.		$2 01	$6 030 000
Deduct maintenance, repairs, towage, etc.,		40%	$2 412 000
	Net revenue		$3 618 000

—or not more than enough to return six per cent. on an expenditure of 60 millions of dollars.

Enough has been brought out in previous discussions before the Society to show very clearly that no inter-oceanic ship canal can be built for anything near the above sum.

If M. de Lesseps could induce the governments of Germany, France, England, and the United States, to furnish the necessary capital, build the canal and present it to the world, to be used free of tolls, and also guarantee its free use at all times, it would be one of the grandest achievements of the century, and its cost would be but a fraction of the annual expenditure of those nations for war purposes, but when he asks us to believe that a sea-level canal at Panama will pay six or even five per cent. on its cost, we must be permitted to doubt very much.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

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CXC.

(Vol. IX.—April, 1880.)

PROGRESS OF WORK AT THE EAST RIVER BRIDGE.

By F. COLLINGWOOD, Member of the Society.

PRESENTED AT THE ELEVENTH ANNUAL CONVENTION, JUNE 17TH, 1879.

The work on the designs for the approaches to the East River Bridge was begun about January 1st, 1877. The Brooklyn approach has a length of 900 feet on the centre line, and starts from the street grade at Sands street, rising $2\frac{8.5}{100}$ feet per 100 to the rear of the Brooklyn anchorage, where it has a height of about 60 feet above ground. It is crossed by several streets at high angles, and has one curve at about 200 feet from Sands street. The width throughout is to be 100 feet.

The New York approach is 1 546 feet long, rising from grade at Chatham street, $3\frac{2.5}{100}$ feet per 100 feet to the rear of the New York

anchorage, where it is 68 feet above ground. It will be 100 feet wide for about 500 feet from the entrance, and 85 feet for the remaining distance. In Brooklyn all the streets will be crossed by box or plate girders. In New York, Pearl and Cherry streets, together giving an opening 210 feet on one side and 170 feet on the other, will be crossed by trussed girders; Cliff and Vandewater streets by semi-circular stone arches 51 feet 8 inches span; Rose street by a three-centred stone arch, 57 feet span; and William and North William streets by box girders.*

The architectural problem presented was one of considerable difficulty, owing to the requirements in the case. These were that the spaces underneath should be made available for storage or mercantile uses, thus enforcing the necessity of keeping the arches wide enough for this purpose; and requiring, in addition to this, that the structure should be imposing and harmonious in effect.

The design as adopted was a composite one, being based upon one proposed by the writer as to general features, but being modified by the commission of architects as to the style of the arches, and made somewhat more ornamental in detail.

The fronts are entirely of granite. The main features are, massive abutments at each side of each street projecting at the base about 7 feet from the spandrel line. These have an ornamental plinth. The shaft is finished in smooth pointed work with chamfered edges; and the whole is surmounted by facia, cornice, pedestal, and cap. The heaviest cap stones are 17 feet long, 5 feet wide, and 2 feet thick. Between the abutment piers the spaces are divided, so as to give arches varying from 17 to 31 feet span. The small piers between have slightly battered sides, and terminate in ornamental caps or imposts, from which the arches spring. The arches are of the Florentine style, being broadest at the key and narrowest at the spring, thus giving a pointed extrados. This style was adopted by the architects in order to fill up the spandrel space, and not leave so large an amount of dead wall. The key-stones in the largest arches are 8 feet high and weigh about 11 tons. The arches are finished in the same style as the shafts of abutments. The spandrel is of a darker granite, in regular courses, but rock faced.

The cornice over the arches has a dentil course below, surmounted

* This was afterwards changed and stone arches substituted. That at William street is a stone arch of 38 feet span and 6 feet 5 inches rise ; and that at North William street a stone arch of 40 feet span and 5 feet rise.

by a heavy projecting coping course, all in six cut work. (I should have mentioned that the plinths, caps, and pedestals are also of six cut work.)

The cornice is surmounted by an ornamental granite parapet 4 feet high.

The regular thickness of the exterior walls is 3 feet 9 inches. The division walls and interior of the abutments is of brick. The foundations are carried down where the bottom is sound to 3 feet 9 inches above tide, but where sound bottom is not reached at this depth, they go down until it is reached. In one place this was 9 feet below tide. It may be well to record here the finding of trunks of oak trees in the muck at this point, which had no doubt been buried for several centuries. The wood was perfectly sound, and was sawed up into walking sticks. The spot had been built upon for probably 200 years.

The foundations as far as finished were well spread, and, as far as practicable, in such manner as to give a uniform pressure throughout, not exceeding 5 tons per square foot when fully loaded. They were built of concrete, rough stone, and brick work. They were faced with brick always when coming next to a cellar space. When such facings were used tie walls were always carried across, so as to bind the mass together.

All the brick and stone work is set in cement mortar, and the limiting strain on brick in compression is fixed at 200 pounds per square inch. The floors are in this supposed to be loaded, including their own weight, with 450 pounds per square foot, and the roadway above with 100 pounds per square foot.

These are the *limits*, but the actual sections are considerably beyond these figures, and it is not at all probable that the loads mentioned will ever come on the floors.

The present condition of the work is as follows: In New York the stone work of the block next to the anchorage is completed, and in the next two blocks the stone and brick work are completed to the springing of the arches very nearly. This leaves three full blocks and part of another yet untouched, and will require nearly or quite two full seasons' work to complete them. In Brooklyn the work has made about the same progress, but, owing to the shorter distance, it can be finished in about another season.

Owing to the lack of funds the trustees have decided to do nothing more on the approaches at present, so that the time of completion is

indefinite. The part of the work in charge of the writer is the New York approach (the Brooklyn approach being in charge of Mr. G. W. McNulty), but he has deemed it proper to mention both approaches, as they are essentially the same work.

Before closing, it may be interesting to members to mention the methods pursued in setting the stone work. The first thing done in every case, as soon as the ground was cleared of buildings, was to carry forward two lines of railroad track running through the work and at a convenient distance either side of the centre line. Next two lines of derricks were put up, and strongly guyed in such positions as to reach all parts of the pits for excavation, and high enough to set all stone to and including the lowest arch stones. Then, since the walls on the New York side were to reach 68 feet above ground, and the cap stones about 74 feet, it was deemed desirable not to attempt the use of derricks further, but to use a traveling crane. The novelty of this consisted in the method adopted for turning the corners, as it had to set stone on three sides of a square.

The span of the trestle was 16 feet. At the inner angles corner posts were placed, carrying at their upper ends cast-iron turn-tables, the castings being in the form of a T, with the cross about 6 feet long, and forming a portion of the track, and the vertical portion cast hollow and slightly conical, so as to turn freely on the post.

The outer track was carried around with a curve of 16 feet radius. When the crane had traveled forward so that the inner pair of wheels were balanced on the turn-table, a tripping piece threw them suddenly out of gear, and the outer wheels then traveled around the curve while the inner end of the machine pivoted on the turn-table. As the outer wheels reached the tangent again the inner ones were automatically thrown in gear, and the machine again traveled forward. Friction rollers supported the end of the turn-table arm as the weight passed off or on.

The wheel base of the lower carriage was 3 feet 8 inches, and the only caution required was to see that the machine kept square with the track. Owing to the sharpness of the curve, there was considerable noise made in passing around it, but the machine did its work well. The design was elaborated and the machine built by Messrs. Schoener & Allen, of Tamaqua, Pa.

Cable Making at the East River Bridge.

By request of Col. Paine, whose time has been completely taken up by other matters since the cables were completed, I present also the following record of work accomplished in his department:

The last public record was made in the reports for the year 1876, and as these were sent to all the members of the Society, it is deemed sufficient to refer to them for the history of the preparations for cable making.

During the winter of 1876–7 the foot-bridge was completed, the contract made for the cable wire, and all necessary preliminaries settled.

Among these, one of the most difficult was found to be the adjustment of the four wires used as guides in adjusting the cable wires. It was at first thought to be sufficient to fix them by the deflection of the centre span alone; but it was found that the land spans hung at deflections totally different from each other, and, after considerable trouble, it was found to be due to slight differences in diameter and weight of the various lengths of wire.

To overcome this a large number of coils were stretched out, measured and weighed, and enough selected of uniform size and weight to make up the lengths required.

After this the weather had to be watched for periods of perfect calm, when no sun was shining, during which times only adjustments could be made. The whole time thus occupied was about six weeks.

On the land spans the line of reference was a tangent to the curve whose position had been calculated; and on the centre spans it was a level line tangent to the lowest point of the curve. Allowances were made for the temperature ruling at the time.

Another point which was worked up during this winter was the method of joining the coils of wire together. The coupling finally adopted gave from 95 to 98 per cent. of the full strength of the wire, with the coupling ungalvanized; and after galvanizing the joint the *full* strength was developed.

The wire at first specified had a diameter before galvanizing of about 0.167 inches, diameter being Birmingham gauge, No 8, full. The coupling was made from Bessemer steel wire 0.281-inch diameter, and was $1\frac{1}{16}$ inches long. This was drilled longitudinally, and then the hole was

reamed out for about one-fourth of the length in at each end, so as to taper from the full size of the wire at the ends to about the diameter of the bottom of the screw thread at the inner end of the taper. Then one end was tapped with a right handed, and one with a left handed tap. Dies of a similar shape to the coupling were made for cutting the threads on the wire.

At first considerable irregularity in the strength of the joints was observed, and it was found to be due to the dies changing shape in hardening to an amount reaching sometimes $\frac{3}{1000}$ of an inch. This was overcome by making an adjustable die, so as to secure uniformity in size.

The first cable wire was carried across the river May 29th, 1877, and from this time cable making was continuous. At first an unforeseen difficulty was encountered from the unscrewing of the couplings while the wire was in transit. After considerable experimenting a plan was adopted which overcame the trouble perfectly. This was the simple device of clipping the ends of the wires diagonally, so that when the coupling was screwed home they would overlap and effectually prevent the wires from turning separately in the coupling.

Simultaneously with this came the training of the men who adjusted the wires. The adjustment had, of course, to be progressive—first a land span, then the centre span, and finally the opposite land span.

The differences in weight of similar lengths of wire showed itself here often by making one quarter hang high and another low. The adjusters were in such cases instructed to make the differences equal, so as to balance each other, thus securing uniform lengths and a perfect adjustment. Marks were made on the wire with paint as soon as an adjustment was complete at any point, so that slipping could be at once detected.

The first strand was completed and lowered into position and attached to the cable bars on July 14th, 1877. As it would be impossible to *lengthen* a strand, all strands were made by preference a trifle too long, and adjusted to length after lowering. To allow of this the shoes over which the wires pass at either end have a slot through them instead of a round hole, and segments are inserted back of the pin to secure the exact length.

The lowest or *first* strand in each cable was adjusted in the same manner as the guide wires had previously been; and the succeeding ones were adjusted from these by calculating differences in elevation due to

their own particular lengths. The differences in *length* were due to different positions in the saddles, different points of attachment at the cable bars, cradling of the cables, &c., and it will be seen that the process of adjustment was an exceedingly delicate one.

It was usually done very early in the morning to avoid differences in temperature.

When the strands were finally brought together for wrapping, each one came to its place admirably, much to the satisfaction of all concerned.

The experience on the first strands showed that there was no difficulty in getting the requisite quality of wire; and it was then decided that as larger wire could be had which would comply with the specifications, and as its use would facilitate the work, its size should be increased from No. 8 to No. 7 wire, which is about 0.187½ inches diameter.

This gave, instead of 14 feet to the pound, about 11 feet to the pound, and made a material difference in the length to be run out.

The speed of the traveler averaged 5½ feet per second, and as the wire ran out at twice this rate, 11 feet of wire were run out per second by one, or 22 feet when both travelers were working.

In order to keep the strands distinct, and also to prevent chafing, they were, after completion and before lowering, seized throughout their length, at points 2 feet 4 inches apart, by about 5 turns of No. 14 annealed wire. These seizings were removed always in advance of core making or cable wrapping.

After twelve strands of a cable were completed, the central seven (being the ones which were to occupy the centre of the finished cable) were brought together compactly, to form the cable core. This was done by the aid of screw clamps; the outer strands being pounded with wooden mallets so as to distribute the wires uniformly around the central one of all. A fresh seizing was put on the core at short distances as the compressing progressed.

Everything went on well until June 14th, 1878, when the fifteenth strand of the up town cable was in process of lowering. By the unfortunate fouling of a wire rope, causing its rupture, the strand fell, killing two men, and causing a total loss of the strand.

The last wire in the cables was run over October 5th, 1878. The next operation was to draw all the strands in each cable together at each end

to a true cylindrical form. This was done, and heavy clamps put on at 21½ feet from the anchor bars. It must be borne in mind that at the point of joining with the anchor bars the strands spread to a rectangle nearly 5 feet square; hence the necessity for permanent clamps at the points mentioned.

Regular work on cable wrapping began October 25th. The wire used for this purpose was charcoal iron wire No. 10, drawn a little hard and galvanized. As the wrapping was done, every part of the cable was saturated with linseed oil.

The coils of wrapping wire were joined together by a twist splice. The two ends to be joined were tapered for about 4 inches, then twisted together, and the whole swaged. This left but a slight enlargement, which passed readily through the wrapping machine. Every joint was finally galvanized. The operation of cutting the seizings of the core and flatting out the external strands, &c., preceded the final wrapping also—the ends of the seizings being pulled out with pincers and hooks. Clamps were screwed on in advance to bring the cable wires into close contact, and the wrapping wire was put on under considerable tension. It is calculated that the friction between the wires is so great that if cut it would be impossible to pull out 10 feet of any cable wire, as the friction in that length would more than equal its tensile strength.

The speed of wrapping was from 16 to 20 feet of cable per day per gang, 36 feet being an extreme limit.

The work was completed finally on February 17th, 1879, or in about 15 months less time than was thought possible when it began.

During the summer of 1878 the suspender ropes were all cut to length, and sockets attached. As the ropes are all of twisted wires it was necessary (to secure accurate lengths) that they should be measured under strain. Accordingly one socket would be attached, the rope uncoiled and stretched out, and the socket put over a pin; then, by an ingenious parallel motion clamp, made to grip the rope without injuring it, a strain of about 6 tons would be put upon it, and the requisite length marked off. The old method of cutting was by a chisel and sledge, and was very tedious; it always separated the wires, and caused much trouble in inserting them into the socket. To obviate this Mr. Abbott, assistant in charge, designed a circular cutting shears, which, instead of separating, compressed the wires together, and resulted in a saving of an hour on

every socket. It ought here to be said that the clamp mentioned, and also the machine for clipping the ends of the wire diagonally, were designed by Mr. Abbott.

The method of fastening pursued in every case was to let the wires project a little beyond the cone of the socket, then to untwist and separate them as widely as possible; next, to drive in all the large iron pins (with a taper equal to that of the socket, and length a little less) that could be inserted; then to follow these by shorter and smaller pins until it was impossible to drive in any more; the wires were then bent over upon the heads of the pins, and finally all poured full of lead to keep out the weather.

As the *strongest* wires would be those approaching nearest to the minimum of ductility allowed by the specifications, they would frequently break under this bending test, which was much more severe than the specifications required (being almost a right angle, and accompanied by a blow). The number broken reached from one-eighth to one-fourth of all; but as the bending down of the ends was not relied upon for strength, no harm can ensue. The friction of the pins is entirely sufficient to break the rope.*

The cables to the foot-bridge were made of a much harder wire, and even more of them broke in putting on the socket, but no sign of yielding has ever occurred, although they are subjected to about three times the strain, in proportion to their strength, that will ever come upon the suspenders.

The strain put upon each rope, when cut to length, was nearly up to its full working strength, and not a socket yielded in the least. These facts are mentioned to show that with proper care this method of fastening is absolutely secure.

The bands for attaching the suspenders to the cables have all been made, and will probably be put in place during this summer.

I have thus given a brief summary of the leading facts concerning this portion of the work; but it would seem desirable that a statement should be made of some of the results of our experience in the use and testing of steel:

1st. Referring to steel wire, it has been satisfactorily demonstrated

* Tests since made on full length ropes have proved this to be true, and also that the wire, both in ductility and tenacity, was above the requirements of the specifications.

that no satisfactory test of the elastic limit, or amount of stretch, can be made on wire drawn and coiled in the ordinary way, on account of the set induced by coiling.

2d. The elastic limit of straight wire was found always to be more than 50 per cent. of the ultimate strength.

3d. There is no difficulty in getting steel wire that shall lay out straight when loosened from the coil. It simply requires that it be led straight a sufficient distance from the galvanizing trough to be cooled before coiling, and that the coils be not made too small. Our coils were 4½ feet in diameter.

4th. Galvanizing was found to increase the strength of freshly drawn wire *about* 15 per cent. It was a common thing for ungalvanized wire which fell below the required strength to come up to it after a week or two, the gain being nearly 5 per cent. Even galvanized wire would gain in strength slightly by rest. The only explanation of this is the accommodation of strains induced by the drawing. In the case of galvanized wire, however, there may be a remnant of occluded hydrogen, due to the galvanizing process, which is known to have a temporary weakening effect.

5th. Steel wire can be had in quantity of a tensile strength of 160 000 pounds per square inch, with a stretch of 2½ per cent. in breaking in 100 feet lengths; and of 4 per cent. in breaking in 1 foot lengths; and capable of being coiled continuously around a ½-inch bar.

6th. The steel required to give this strength in wire of sizes No. 7 and No. 8 B. W. G., when in sizes such as are required for *ordinary bridge* members, has a strength of only 70 000 pounds to 75 000 pounds per square inch, with an elastic limit of 40 000 pounds, and a stretch of 10 per cent. on full length of bar, or 15 per cent. on samples 1 foot long.

7th. Tests by impact, made by allowing weights to fall lengthwise, of wire having a tensile strength of 3 400 pounds per wire, gave results as follows:

A 100 pound weight falling freely $3\frac{7}{10}$ feet broke a wire 1 foot long. The same weight fell 34 feet to break a wire 100 feet long.

The amount of work done in the first case by the weight was 370 feet pounds; and in the second case 3 400 feet pounds.

8th. A logical deduction from these experiments is that the longer the members in a bridge the *safer* it becomes to use high grade material; and, while it is absolutely safe to use wire such as was used in the cables

of the East River Bridge in members of that length, it would be totally *unsafe* to use anything approaching such material in the trusses of the same.

In making specifications recently for steel for the bridge trusses the requirements as to quality were those mentioned in the sixth head above. Previous to this bids had been asked on the basis of wrought iron, for the reason that only a year ago it was questionable whether proper shapes could be produced in this country in steel. This difficulty having been overcome, and the continued tests of steel by Col. Paine having more fully demonstrated the desirability of using steel, Col. Roebling and the Trustees decided to ask bids anew for an all steel bridge. The field is a new one, and the engineering department has endeavored to make use of the latest knowledge on the subject, and at the same time to be entirely safe.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

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CXCI.

Vol. IX.—May, 1880.

ON THE VARIATION DUE TO ORTHOGONAL STRAINS IN THE ELASTIC LIMIT IN METALS, AND ON ITS PRACTICAL VALUE AND MORE IMPORTANT APPLICATIONS.

By ROBERT H. THURSTON, A. M. C. E., Member of the Society.

READ APRIL 7TH, 1880.

The writer has, in various earlier papers,* called attention to the important effects of strain in metals in the elevation of the normal elastic

* Increased Resisting Power of Metals under Stress. *Journal Franklin Institute*, 1873; *Iron Age*, 1874; *London Iron*, 1874; *Pract. Mechanic*, 1874; Pamphlet, 8vo., Phila., 1874.

Strength, Elasticity, Ductility and Resilience of Materials of Construction. Trans. Am. Soc. C. E., 1874; *Dingler's Polytechnisches Journal*, 1874; *Journal Franklin Institute*, 1874; Pamphlet, 8vo., Phila., 1874.

Resistance of Materials as affected by Flow, &c. Trans. Am. Soc. C. E., 1876.

Rate of Set of Metals subjected to strain for Considerable Periods of Time. Trans. Am. Soc. C. E., 1876; *Iron Age*, 1877; *Dingler's Journal*, 1877.

limit, and has shown that strain in tension causes in iron a permanent exaltation of that limit, which exaltation may be subsequently taken as a measure of the strain upon which it is consequent; thus overstrain causing accident may be detected by the permanent record so left in the altered character of the metal.*

After a long series of experiments and special investigations, the results of which will be found in papers presented at various dates to the American Society of Civil Engineers, the writer fully determined these facts, and confirmation was found in the researches of Beardslee and others. It was also found by the writer that a definite law governed this exaltation of the elastic limit, relating its amount to the time allowed for set to take place, and to the rate of distortion by unintermitted stress. This law was expressed by a formula† of the form

$$El = a \log.\ t + c.$$

in which, though very variable with differing qualities of metal, for good bridge and cable irons, a=5; c=1.5; El=per cent.; t= time in hours.

The fact was discovered during researches conducted by the writer in the Mechanical Laboratory of the Stevens Institute of Technology, that this same modification of the elastic limit occurs when metals are transversely strained, and this was announced to the American Society of Civil Engineers in a paper‡ presented March 1st, 1876, in which it was shown that in what was called the "iron-class," comprehending both iron and steel, this effect is one of elevation, while, as had been already also shown, on the "tin-class," including the brasses and the bronzes, the effect is to depress the normal elastic limit. Strain-diagrams exhibiting the behavior of the several kinds of metal under these strains, were given as conclusive evidence of the facts presented.

The fact that a permanent distortion of a piece of iron increases its stiffness had been long known. Bell-hangers had, from some unknown but very early date, been in the habit of stiffening wire and guarding

* On a New Method of Detecting Overstrain in Iron and other Metals, and on its Application in the Investigation of the causes of Accidents to Bridges, &c. Trans. Am. Soc. C. E., 1878; *Sci. American Supplement*, 1878; *Van Nostrand's Mag.*, 1878.

† Ibid.

‡ Note on the Resistance of Materials as affected by Flow and by Rapidity of Distortion. Trans. Am. Soc. C. E., 1876.

against subsequent stretching while in use, by straining it considerably before putting it in place. As early as 1850 Clarke remarked,* " * * * * * if the compressed and extended portions of a wrought iron bar could be, by any artificial means, permanently strained previously to its employment as a beam, such a beam would deflect less than a new bar, and would be practically a stronger beam, since the strength is regulated solely by the bending of the bar."

This idea was also practically applied in 1854 by Werder, at Munich, who stiffened his rods before placing them in the structure, by giving each a permanent extension by tensile stress exceeding the primitive elastic limit. Neither of these, nor the later experiments of Bauschinger (1873) and others, led to the discovery of the elevation of the normal parabolic curve of successive elastic limits, *per saltum*, as finally discovered by the writer, and corroborated by Beardslee, but the increased stiffness noted was attributed to that general, normal, and invariably regular, elevation of the limit by increasing strain, which is seen in all cases and with all materials, and which produces a smooth and usually parabolic strain-diagram.

The writer has now noted and brought to the attention of engineers the fact that the exaltation of the normal elastic limit due to any given degree of distortion in the "iron-class," and its depression in the "tin-class," occurs under intermitted strain, whether the stress be applied longitudinally, transversely, or by torsion, and has presented experimental data proving this phenomenon to thus occur, and experimental quantitative determinations of the law of its variation with time, and the amount of such variation.

He has now to present still another interesting and probably important phenomenon of similar character.

It seemed probable that, if strain in either direction, when exceeding the elastic limit, always produces variation of the normal position of that limit, this effect must be due to a general modification of molecular relations that should modify the effect of the force of cohesion in other directions than that in which the strain had been given. An investigation was made, and this matter was experimentally studied, as opportunity permitted, in the Mechanical Laboratory of the Stevens Institute

* Account of the Brittannia and Conway Bridges, 1850. See "Mechanical Treatment of Metals," by R. H. Thurston, *Metallurgical Review*, 1877, p. 272.

of Technology, until sufficient data was accumulated to give conclusive determinations.

Iron and steel wires broken by tension were found to have the transverse elastic limit abnormally elevated, and to have become very stiff and of comparatively slight ductility. This was true of wires of other metals, and of heavier sections of metal. A large quantity of cold-rolled shafting of all sizes, of which both the longitudinal and the transverse dimensions had been altered by rolling cold, exhibited great increase of stiffness and strength and an even more considerable exaltation of the normal elastic limit. Torsion similarly stiffened wires and rods longitudinally, and test pieces longitudinally strained, become stiffer against torsionally and transversely applied stress. Thus, orthogonal strains mutually affect orthogonal resistances of metals; and the engineer is, by this fact, compelled to study these mutual influences in designing structures in which the stresses approach or exceed, separately or in combination, the normal *primitive* elastic limit of his material.

The following is, in detail, an account of the behavior of a bar of "good merchant iron" under the action of intermittent and successively applied orthogonal strain (transverse succeeded by tension):

A bar of good bridge or cable iron 2 inches square and about 4 feet long was split longitudinally; one-half was cut into tension test pieces, and the other half bent on the transverse testing machine to an angle at the middle of about 120 degrees; the bent bar was then cut into tension test pieces like the first, and finally all these pieces were broken in tension.

On examining the results thus obtained it was found that the original elastic limit of the metal, as exhibited by the test of the unbent bar, had been exalted by transverse strain in all parts of the bar which had been so strained before being tested by tension. This elevation of the primitive normal limit had not occurred, as would have been expected, to the greatest extent at the points most strained,—*i. e.*, nearest the bend at the middle of the strained bar—and less and less as the point of maximum strain was departed from, until, at the ends of the bar, this elevation became much less observable; but it took place irregularly, and, on the average, about as much at one part as at another.

The following are the figures obtained (the bent bar was cut into eight and the unbent into six pieces, and numbered consecutively from end to end):

I.—Effect of Transverse Strain on the Tensile Elastic Limit.

(Elastic limit in pounds per square inch, and kilograms per square millimetre.)

Unbent Bar.			Bar Strained by Bending.		
	Kg. per Sq. m.m.	Lbs. per Sq. In.		Kg. per Sq. m.m.	Lbs. per Sq. In.
No. 1.....	16.3	23 300	No. 1¹.....	21.6	30 900
" 2.....	16.7	23 800	" 2¹.....	23.5	33 500
" 3.....	16.9	24 100	" 3¹.....	18.2	26 000
" 4.....	16.4	23 400	" 4¹.....	19.6	28 000
" 5.....	14.6	20 800	" 5¹.....	22.4	32 000
" 6.....	15.7	22 400	" 6¹.....	19.6	28 000
			" 7¹.....	22.4	32 000
			" 8¹.....	19.8	28 200
Average.....	16.1	22 967	Average...	20.9	29 825

The elevation of the primitive elastic limit, in this instance, is thus seen to have been 30 per cent., as an average, and in some parts of the bar about 50 per cent. The new series of the elastic limits are seen to be less uniform in value than in the original bar; but, comparing adjacent pieces, in no case is the elevation of the limit less than 1 ton on the square inch, and it usually amounts to more than double that figure. Singularly, also, the greatest change has been produced farthest from the middle, and the least at that point (Nos. 1 and 6, at the ends of the unbent bar, correspond to 1 and 8 of the other; and 3 and 4 of the first and 4 and 5 of the latter correspond, both pairs being from the middle).

It should be observed that the quality of the bar tested, although good as metal of that size runs in the market, is not high, and is not as regular as it should be. It is a "50,000 pound iron."

But the transverse strain here produced, and which is seen to have so greatly modified the primitive elastic limit of the metal, had not materially or even observably affected its ultimate tenacity; this is seen by a comparison of the results of tests *to* the point of fracture, thus:

II.—Effect of Transverse Strain on Ultimate Tenacity.

(Tenacity in pounds per square inch, and kilograms per square millimetre.)

Unbent Bar.			Bar Strained by Bending.		
	Kg. per Sq. m.m.	Lbs. per Sq. In.		Kg. per Sq. m.m.	Lbs. per Sq. In.
No. 1.....	40.9	58 450	No. 1[1].....	34.1	48 700
" 2.....	34.5	49 330	" 2[1].....	34.7	49 500
" 3.....	35.4	50 520	" 3[1].....	33.5	47 900
" 4.....	35.6	50 980	" 4[1].....	37.5	53 600
" 5.....	36.8	52 540	" 5[1].....	36.4	52 000
" 6.....	30.1	42 980	" 6[1].....	36.8	52 600
			" 7[1].....	36.2	51 700
			" 8[1].....	33 4	47 700
Average.....	35.6	50 800	Average.....	35.3	50 475

It is seen that the two averages are as nearly identical in value as could be expected, and that the average ultimate resistance to rupture was apparently not altered by the straining due to transverse stress.

Yet, noting the difference of the figures for adjacent parts of the two stripes into which the original bar was split, we may make an interesting comparison, thus:

III.—Effect of Transverse Strain in Elevating the Primitive Elastic Limit and Ultimate Tenacity.

(Differences by comparing Tables I and II.)

	Elevation of Elastic Limit.		Increase of Ultimate Tenacity.	
	Kg. per sq.m.m.	Lbs. per sq. In.	Kg. per sq.m.m.	Lbs. per sq. In.
No. 1¹ No. 1.....	5.3	+ 7 600	6.8	— 9 700
" 2¹ " 1.....	4.1	+ 10 200	6.3	— 8 950
" 3¹ " 2	1.6	+ 2 200	1.0	— 1 430
" 4¹ " 3.....	2.2	+ 3 900	2.2	+ 3 080
" 5¹ " 4	6.0	+ 8 660	0.7	+ 1 020
" 6¹ " 5.....	5.0	+ 7 200	0.1	+ 160
" 7¹ " 6.....	6.7	+ 9 600	6.1	+ 8 720
" 8¹ " 6.....	4.1	+ 5 800	3.3	+ 4 720

(We compare No. 3 with No. 4¹ and No. 4 with 5¹, because the middle of the bar falls, in the one case, between 3 and 4, and in the other, between 4¹ and 5¹.)

On examination of these figures we are struck by their irregularity, by the fact that the greatest changes both of elastic limit and of tenacity are produced at the ends of the bar, and by the singular phenomenon of an apparent *decrease* of tenacity at one of the ends of the bar. It seems improbable, however, that the latter effect can have been consequent upon any deformation of the bar ; it may be more probably attributable to local defect in that end of the strained strip, due to cinder streaks. From the irregularity noted it seems evident that good iron, so called, may possess—as indeed inspection usually indicates—great local defects.

Again, Bars of iron were subjected to severe lateral compression, increasing their length and decreasing their cross section about 15 per cent.; then testing the metal by longitudinal strain, *i.e.*, by orthogonal stress, the writer obtained the following average figures :

TESTS BY TENSION AFTER LATERAL COMPRESSION.

ELASTIC LIMIT.		TENACITY PER UNIT OF AREA.				EXTENSION.	MODULUS OF ELASTICITY.
		Original Section.		Fractured Area.			
Lbs. on Sq. Inch.	Kg. per Sq. m.m	Lbs. per Sq. In.	Kg. per Sq. m.m	Lbs. per Sq. In.	Kg. per Sq. m.m	Per Cent.	Lbs. on Sq. In.
Unstrained Bar 30 000	21	52 500	36.5	89 870	64	24.6	25 270 750
Strained Bar... 59 000	42	69 000	49.	105 600	75	10.4	26 230 500

Thus it is seen that lateral compression to this moderate extent may elevate the longitudinal elastic limit nearly 100 per cent., may increase the longitudinal tenacity 33 per cent. and may raise the modulus of elasticity 4 per cent., while decreasing the ductility in the orthogonal direction 60 per cent.

A similar experimental determination of the effect of equal lateral compression on resistance to flexure gave the following figures :

FLEXURE AFTER LATERAL COMPRESSION.

Cylindrical Bars 1½ in. diam. x 40 inches between supports (2.8 c. m. x 1 m.)

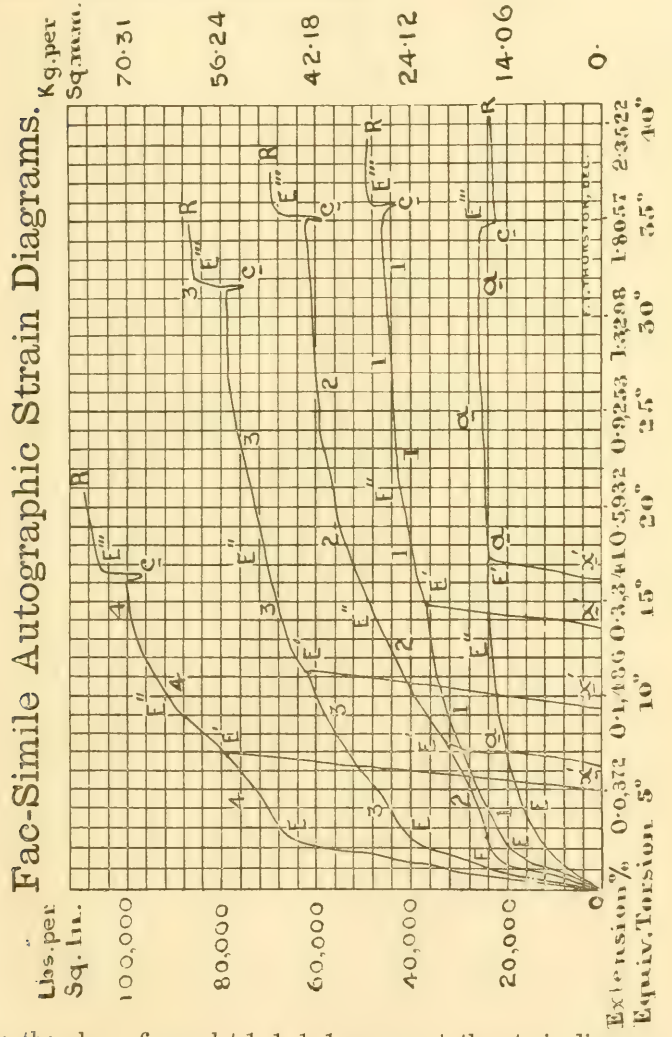
LOAD AT ELASTIC LIMIT.		MODULUS ELASTICITY.	MAX. LOAD.		RESILIENCE AT MAX. DEFLECTION.	
Lbs.	Kilog.	Lbs. per Sq. In.	Lbs.	Kilog.	Ft. Lbs.	Kg. m.
Unstrained Bar.. 1217	553	27 174 500	1870	850	552	76.5
Strained Bar..... 2700	1227	25 691 500	3395	1543	1049	145.

Thus lateral compression to the extent here practiced increased the elastic limit in flexure more than 100 per cent., *reduces* the modulus of elasticity as estimated from flexure 6 per cent., increases the maximum resistance 90 per cent., and nearly doubles the resilience at maximum deflection (4 in. = 0.1m).

From the fact that the changes produced by cross-bending are felt in internal strain occurring, not simply near the point of flexure, but throughout the whole extent of the beam flexed, it would seem that shearing strains are more serious and general than we have hitherto supposed. This latter is a matter of importance in determining a correct theory of transverse strain, and the subject is undoubtedly deserving of extended and careful investigation with a view to discovering precisely the nature and intensity of such strains under all usual conditions in all

the materials of engineering construction—first feeling out these strains in the manner here indicated, and then working up the details of the theory until a complete and satisfactory analysis is attained.

Conclusions :—We may now summarize the results of the study of this subject, so far as the writer has yet presented them, and the conclusions to which he has been conducted.



In the above figure, let 1 1 1 1 represent the strain-diagram of a soft, malleable (wrought) iron, like Swedish or Norway ; let 2 2 2 2

be that of a good common merchant iron of small size ; let 3, 3, 3, 3, be the diagram of a mild, and 4 4 4 4 that of a tool steel ; while, in contrast to these examples of the "iron-class," let *a*, *a*, *a*, *a*, be the strain-diagram of a metal of the "tin-class;" for example, a ductile brass or bronze.

When these metals are strained, they are always found to exhibit a gradually increasing resistance pretty nearly proportional to the extent of change of shape, until a point, *E*, is reached, when the rate of increase of extension becomes greater—usually very much greater—and the deformation remains permanent when the piece is unloaded, and very nearly equal to the distortion under the load. The removal of the load then, if it is not renewed, gives a strain-diagram *O*, *E*, E^1, x^1, the distortion being permanent at x^1. This is the natural or "normal" curve, and it exhibits the normal and long known form of elevation of elastic limit. At the last moment, when the load and distortion are measured by the ordinate and the abscissa, respectively, of the point E^1, the elastic limit has become a maximum. Had the piece strained broken at E^1 the limit of its elasticity would have become identical with the limit of strength and point of rupture, and its measure would have become identical with the modulus of rupture ; for, considering the piece as unbroken at this point, the distorted piece would have for its strain-diagram the straight line E^1, x^1, and would have now been broken when loaded, at the moment that the stress attained the magnitude measured by the vertical let fall from E^1 to the base line. The point *E* on each diagram marks what is usually known as the Elastic Limit. To distinguish this from the successive limits of elasticity which are due to permanent successively increasing strains, the writer has called the natural and original apparent limit of elasticity, *E*, the "*Primitive Elastic Limit*," and any other points, E^1, E^{11}, in a smooth curve representing a strain-diagram exhibiting the effect produced by unintermitted and regular distortion, the "*Normal Elastic Limit*" of the piece when in such condition of deformation, the whole curve being, as has been stated, a "*Curve of the Loci of successive Elastic Limits.*"*

This normal elevation of the elastic limit, therefore, as strain progresses and permanent deformation increases, occurs regularly, and the

* On the Mechanical Treatment of Metals, and on the Elevation of the Elastic Limit. R. H. Thurston.—*Metallurgical Review*, 1877.

Ueber die Natur der Elasticitälsgrenze und die Art Ihrer Veranderungen. R. H. Thurston. —*Dingler's Polytechniches Journal*, 1877.

strain-diagram takes the form of a smooth curve such as has been long known to represent it, and such as will be found in Morin's "Resistance des Matériaux" and other works published during the last quarter century.

But, instead of producing a regularly increasing deformation by regularly increasing stress, let load be steadily added until at some point E^{III}, corresponding to a distortion O, E^{III}, further addition of load ceases, and the piece remains permanently distorted. The metal now gradually yields, and there occurs a depression, c, of the elastic limit, which in the iron-class soon reaches a limit, but in the tin-class, if the load be not wholly or partly removed, may continue until rupture or maximum possible deformation takes place. Now, renewing the stress, it is invariably observed that this depression of elasticity is, in the case of the iron-class, only apparent; for the extension of the strain-diagram now takes place at a higher range, E^{III} R, and we observe at E^{III} that phenomenon of "Exaltation of the Normal Elastic Limits" which has been studied by the writer, as seen at E^{III} in curves 1, 2, 3 and 4, and which has until recently been unnoticed by authorities.

Making the same experiment on metals of the tin-class, we usually observe the depression of the normal succession of elastic limits which distinguishes this class from the first, as at E^{III} in $a\ a\ a\ a$; sometimes, however, this depression is unobservable.

This distinction between the two kinds of metals has been shown to have peculiar importance in its bearing upon the permissible values of the factor of safety in structures of metal, the value allowable in constructing in iron or steel being lower, and that demanded in parts composed of the second class of metals being higher than would be proper except for this singular characteristic.

Studying the effect of rapidity of distortion, we find that in the case of the iron-class greater rapidity of distortion causes a decreased resistance, and that a slowly produced deformation causes relatively higher resistance, while the opposite is the case with metals of the second-class.* We see that the rate of set is also related to the time allowed for it.† It thus happens that with the same metals strained at such a rate as to give a strain-diagram 1 1 1 1, an accelerated distortion may produce the

* On the Resistance of Materials as affected by Flow and by Rapidity of Distortion. Trans. 1876-7.

† On the Rate of Set of Metals. Ibid.

diagram 2 2 2 2 or the diagram *a a a a*, accordingly as the metal is of the first or the second class.

Still further, it has been shown in the earlier part of this paper that the exaltation of the elastic limit in iron, &c., is not confined to the direction of the strain produced, but that it affects the metal in such manner as to give it an exalted elastic limit with respect to all subsequent strains however applied. Thus, the engineer may make use of any method of strain that he desires or that he may find convenient, to secure the condition of increased stiffness that he may desire in any given direction. He may strain his bars in tension to secure stiffness in either tension, compression or transversely, or he may give his bars a transverse set to obtain a higher elasticity in all orthogonal directions, or he may compress the metal, as by cold-rolling, and thus secure enhanced stiffness and elasticity in either longitudinal or transverse directions.*

Finally, the writer having shown that the exalted elastic limit being a permanent and determinable effect of any strain which exceeds the "primitive elastic limit," it must remain a permanent and ineffaceable record of the maximum load borne by the metal; this fact is seen to be of inestimable importance, as it enables the engineer to trace such distribution of strain as may have occurred in a wrecked structure,† to determine the location of defective and flawed pieces, and to ascertain the distribution of strains generally, whether in structures or in single members.

This last suggestion may, perhaps, prove of more value to the profession than that relating to the increased safety due to this exaltation of the normal limit of elasticity. The value of this method of investigating experimentally the distribution of stress with a view to determining a correct theory of resistance of materials and of stress, is also probably obvious to every student of the imperfect and largely hypothetical mathematical method of treatment of the subject now usual.

These practical, readily applicable and exceptionably important facts seen to be derivable from a careful and intelligent study of the position and of the method and extent of Variation of the Elastic Limit in metal, whether in single masses exposed to strain, or in structures, lend full

* See report by the writer, "On the Strength, Elasticity, Ductility and Resilience of Cold-rolled Iron and Steel." Pamphlet, 8vo, Pittsburgh, 1878.

† On a New Method of Detecting Overstrain, &c., and its Application in the Investigation of Causes of Accident to Bridges and other Structures; Trans. Am. Soc. C. E., March, 1878.

confirmation to the remarks of the writer before the American Society of Civil Engineers, when first presenting this need of studying the elastic limit more carefully even than the ultimate resistance of metal:*

"In determining the value of materials of construction, it is usually more necessary to ascertain the position of the limit of elasticity and the behavior of the metal within that limit, than to determine ultimate strength, or except, perhaps, for machinery, even the resilience. The fact is becoming recognized that it should be possible to test every piece of material which goes into an important structure, and *to then use it* with confidence that it has been proven to be capable of carrying its load with a sufficient and known margin of safety. * * * The method here described" (by use of the Autographic Testing Machine) "allows of this practice with perfect safety. The limit of elasticity occurs within the first two or three degrees, and as seen, the standard specimen may be twisted a hundred or even sometimes two hundred times as far without even reaching its maximum resistance, and often far more than this before actual fracture commences. It is perfectly safe, therefore, to test, for example, a bridge rod up to its elastic limit, and then to place it in the structure with a certainty that its capacity for bearing strain without injury has been determined, and that formerly existing internal strain has been relieved. The autographic record of the test would be filed away and could at any time be produced in court as evidence—like the 'indicator diagram' of a steam engine—should any question arise as to the liability of the builder for any accident, or as to the good faith displayed in fulfilling the terms of his contract."

We now see that beyond all this lies open to the Engineer a wide and important field of study, and that in the knowledge attainable by an investigation of the characteristics of the metal used in construction, as revealed to him by its behavior far within the limit of final or even incipient rupture, and as pictured in the strain diagram, he may find precisely that knowledge which is most essential to him where either economy or safety is of primary importance.

The subject is only just beginning to secure the attention that its importance demands, but it is to be hoped and fully anticipated that we may soon learn much more in relation to it, and that Engineers will ere long make daily application of facts now discovered and of methods already made familiar to them.

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* Strength, &c., of Materials of Machine Construction; Trans. Am. Soc. C. E., 1874; Reprinted, 8vo, N. Y., 1874.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

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CXCII.

Vol. IX—May, 1880.

EXPERIMENTS WITH APPLIANCES FOR TESTING CEMENT

By ALFRED NOBLE, C. E., Member A. S. C. E.,

WITH A DISCUSSION ON THE SUBJECT,

By D. J. WHITTEMORE, C. E., Member A. S. C. E.

PRESENTED AT THE ELEVENTH ANNUAL CONVENTION OF THE SOCIETY.

The testing of cements has, during the last few years, engaged the attention of many engineers, who have put the results on record. The discrepancies in the results obtained by the same experimenter at different times, and those in the results obtained by different experimenters at the same time, are remarkable. Some of the sources of these discrepancies have been investigated and explained.

Two important causes of discrepancies between the results obtained by different experimenters, are the differences in thoroughness of manipulation, and the difference in the form of moulds and clutches or clips, the first of these causes cannot be removed entirely while the mixing is done by hand, but if some form of mould and clip were generally adopted as a standard, it is probable that with a common method of mixing, more uniform results would be obtained, and the tests made by different experimenters would become comparable. My experience leads me to the conclusion that the selection of the mould and clip will be a difficult matter. This paper will be confined in the main to an account of some experiments in this directton, their object being the selection of a form of mould and clip which would give uniform results and develop the full strength of the cement.

In the construction of a new ship-lock at the St. Mary's Falls Canal, all face-stones were set in mortar of Portland cement. General Weitzel, of the U. S. corps of Engineers, the engineer in charge, required that all this cement should be tested, leaving the details of the work to the writer.

The form of mould adopted is shown on Plate No. II, as Mould No. 1. It resembles the form first used by Mr. Mann, and more nearly the form used by General Gillmore in 1877. The cement and water were carefully weighed, and mixed with a hoe in the box shown on the plate, the blade of the hoe being reduced in width to $\frac{1}{8}$ inch less than the bottom width of the box. All the water required was added at once. The temperature of the water used for mixing was below 40° ; that of the room in which the briquettes were moulded and of the water in which they were immersed was between 60° and 70°. I have no doubt that the mortar can be mixed and ground together much more thoroughly, and in much less time in this way than with a trowel. The mixing, when properly done, is very hard work. With the proportions of 35 of cement to 7 of water, a strong, active man can mix the materials to a plastic mortar in $1\frac{1}{2}$ minutes, though in constant work a somewhat longer time is required. About $\frac{1}{6}$ of the mortar required to fill the mould is put in at a time and carefully tamped, with a light stick shod with zinc to prevent the adhesion of the mortar ; the mortar is finally heaped on the mould, and a pressure applied with a piece of board held in the hands : to prevent the adhesion of mortar to the board the mortar is covered with a slip of paper before applying the pressure. After the

mortar has set the briquette is levelled off to the mould with a broad chisel. Mortar for one briquette only is mixed at one time. The breaking section of the briquette is 1½ inches square.

In my earlier experiments a form of clip was used with which the metal came in direct contact with the briquette at the shoulders; the result was in most cases a break between the points of contact, of one of the clips, as noted by Mr. Mann, although the clips were in such a form that they had no tendency to collapse, which he adduces as the probable cause of this irregular break; whatever may be the cause, the fact remains that in some way, through the contact of the clip, the briquette was so injured at that place as to become weaker than at the smallest cross-section.

The heads of our briquettes were too small to permit drilling holes through them as recommended by Mr. Mann, and, as I wished to make use of the moulds already on hand, I devised (in 1877) the clutch shown on the plate as clutch No. 2. In using this clutch the head of the briquette was seized between the parallel plates of the clutch which were set up against it by set screws. Slips of pure sheet rubber, about ⅛ inch in thickness, were interposed between the plates and the briquette to increase the friction and equalize the pressure. This clutch was too heavy to use in breaking briquettes of American cement a week old, because many briquettes would break in handling with the heavy clutches attached; so the lighter clutch shown on the plate as No. 1, involving the same principle of holding by friction, was devised by Mr. McNaughton, who had charge of the testing room; finally, this last form, with a heavier clamp bar, has been used recently for all kinds of cements.

The average results obtained by this apparatus were remarkably high; the average strength of briquettes of pure Portland cement at the age of seven days was over 500 lbs. per square inch; at one time during the last summer, with a particularly good lot of Portland cement, several hundred tests gave a mean of over 600 lbs. per square inch; a large number of briquettes broke at that age under strains exceeding 650 lbs. per square inch, and a few at strains exceeding 800 lbs. per square inch.

The defects of these clamps found by use are as follows: if too great a pressure be applied to the head of the briquette it will be crushed and the test lost; this occurs frequently with mortars of low tensile and crushing strength, and it requires careful management to apply enough

MOULDS, CLUTCHES AND MIXING BOX FOR TESTING CEMENT.

PLATE II
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXXVI. DEC.
NOBLE ON APPLIANCES
FOR TESTING CEMENT

Scales:
for moulds and clutches, 1/4;
for mixing box, 1/8.

Mould No. 1.

Clutch No. 1.

Clutch No. 2.

Mould No. 2.

Clutch No. 3.

Clutch No. 4.

Mould No. 3.

Clutch No. 5.

Mould No. 4.

Clutch No. 6.

Mould No. 5.

Clutch No. 7.

Mixing Box.

pressure to give the required amount of friction to hold the briquette during the application of the breaking weight without reaching the (considerably higher) degree of pressure which will crush it. Sometimes, during the application of the weight, the clutch would slip, thus throwing the strain aside from the axis of the briquette and giving a lower breaking weight ; the best results were obtained when the pressure was barely sufficient to hold the specimen without permitting the clutch to slip off. Sometimes, when the set screws were not set up sufficiently to hold the briquette, the clutch would slip off, and, on being replaced, the briquette would break with the application of a smaller weight than the one which it had before sustained ; and sometimes the breaking weight would be low without obvious cause. Mortars made from the same barrel of cement, mixed the same hour, would give breaking weights varying as much as 40 per cent. I believed these discrepancies were due mainly to the clutch, for the mortars were mixed and the briquettes moulded very carefully. After the close of work last year I began some experiments to select a better form of mould and clutch.

The several forms experimented with are indicated on the plate as moulds Nos. 2, 3, 4 and 5, and clutches Nos. 3, 4, 5, 6 and 7. In breaking, slips or rings of sheet rubber were placed between the bearing surfaces of the clutches and briquettes.

The moulds Nos. 3, 4 and 5, and the corresponding clutches, are essentially the same in form as those of Mr. Whittemore ; in each form of briquette (No. 2 not included) the shoulder is a frustrum of a cone ; in No. 3 an element of this frustrum makes an angle of 45° with the axis; in No. 4 this angle is 60°; contrary to expectation, briquettes moulded in No. 4 gave considerably less resistance than those moulded in No. 3 ; after a few experiments moulds of form No. 4 were turned out so as to make the angle of the shoulder with the axis 45°. Not enough experiments were made to determine whether this change was a material improvement or not.

The breaking section in each form was $2\frac{1}{4}$ square inches.

In all the experiments the mortar was made without sand. The cement and water for each briquette were weighed and the mould filled in the manner already described. The briquettes were left in the air 24 hours and then kept in the water 6 days ; they were broken immediately after being taken from the water. The tests recorded in tables I. to VI.

were made in a room where the temperature varied from 32° to 80°; those in tables VII. and VIII. were made in a room where the temperature was maintained between 60° and 70°. The water with which the mortars were mixed was of the temperature of melting ice.

TABLE I.

COMPARISON OF MOULDS 2 AND 3.

When Made.	Composition		Mould No. 2.				Mould No. 3.				
	Cement.	Water.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variat. of breaking weight from mean, per cent.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variat. of breaking weight from mean, per cent.	
1878.											
Dec. 2	38½	8	No. 3	950 1100 1050	1033	8	No. 5	963 1012 988	988	3	
" 4	35	7	No. 3	969 981 956	969	1	No. 5	950 1100	1025	7	Imperfect.
" 7	35	7	No. 3	894 1069 937	967	10	No. 5	975 1144 1062	1060	8	O. F. Alsen & Co.'s Portland Cement.
" 10	35	7	No. 3	987 938 1019	981	4	No. 5	925 944 1112	994	12	
" 12	35	7	No. 3	925 969 969	954	3	No. 5	1125 1094	1109	1	
1879.											
Jan. 28	35	6¾	No. 3	881 881 888	883	1	No. 5	925 1200 913	1013	18	
" 29	35	6¼	No. 3	862 875 830	858	2	No. 5	1000 1025 1187	1071	10	
Feb. 13	35	7	No. 4	.... 919 931	925	1	No. 5	919 931 1031	960	7	Knight, Bevan and Sturges' Portland Cement.
" 14	35	7	No. 4	863 856 825	848	3	No. 5	1037 1013 937	996	6	
Mean...	.....	.....	.....	.....	936	$3\frac{7}{10}$	.....	.....	1020	8	
Extreme	.....	.....	.....	.....	.....	10	.....	.....	.....	18	

TABLE II.

Comparison of Moulds 3 and 4.

When Made	Composition		Mould No. 3.				Mould No. 4.				
	Cement,	Water.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	
1879.											
Jan. 28	35	6¾	No. 5	925 1200 913	1013	18	No. 6	800 825 875	833	5	O. F. Alsen & Co.'s Portland Cement.
" 29	35	6¼	No. 5	1000 1025 1187	1071	10	No. 6	863 944 1006	938	8	
Mean...	.....	.....	.....	.....	1042	14	.....	.....	885	6½	
Extreme	.....	.....	.....	.....	.....	18	.....	.....	.....	8	

TABLE III.

Comparison of Moulds 3 and 5.

When Made.	Composition		Mould No. 3.				Mould No. 5.				
	Cement.	Water.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	
1879.											
Feb. 13	35	7	No. 5	919 931 1031	960	7	No. 7	838 762 950	850	12	Knight, Bevan & Sturges' Portland Cement.
" 14	35	7	No. 5	1037 1013 937	996	6	No. 7	862 869 813	848	4	
Mean...	.....	.....	.....	.....	978	6½	.....	.....	849	8	
Extreme	.....	.....	.....	.....	.....	7	.....	.....	.....	12	

The experiments show that Mould No. 3 developed greater tensile strength, and Mould No. 2 gave more uniform results, than the other patterns.

The next experiments were made to determine whether the application of pressure while the mortar is setting, results in improvement in strength and uniformity. The plate shows a follower in the upper end of moulds 3, 4 and 5. A weight was applied to this, equivalent to 32 lbs. per square inch of section of the head of the briquette ; after the application of this weight for two minutes, the follower was secured in place by the set screws, and the weight removed. An experiment appeared to show that the full effect of the pressure, as regards the strength of the briquette, was obtained in this way.

The briquettes made in Mould No. 2 were formed as described on pages 3 and 4, without the final application of pressure while setting.

TABLE IV.

Comparative strength of briquettes made in Mould No. 2 in the ordinary manner, and briquettes made in Mould No. 3, setting under a pressure of 32 lbs. per square inch.

When Made.	Composition		Mould No. 2.				Mould No. 3.				
	Cement.	Water.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	
1878.											
Dec. 23	35	7	No. 3	1150 / 937 / 1119	1069	12	No. 5	1625 / 1331 / 1500	1485	10	O. F. Alsen & Co.'s Portland Cement.
" 24	35	7	No. 3	1000 / 975 / 956	977	2	No. 5	1275 / 1675 / 1206	1370	20	
" 26	35	7	No. 3	1062 / 1075 / 1013	1050	4	No. 5	1655 / 1469 / 1469	1531	8	
" 27	35	8	No. 3	950 / 950 / 850	917	7	No. 5	1325 / 1350 /	1338	1	
" 28	35	8	No. 3	994 / 912 / 888	931	7	No. 5	1188 / 1325 / 1337	1283	7	
1879.											
Jan. 25	35	6½	No. 3	938 / 956 / 1012	969	4	No. 5	1487 / 1488 / 1450	1475	2	
" 27	35	6½	No. 3	994 / 969 / 1087	1017	7	No. 5	1650 / 1638 / 1687	1658	2	
" 30	35	7½	No. 3	1081 / 975 / 1100	1052	7	No. 5	1375 / 1412 / 1125	1304	14	
Feb. 1	35	7½	No. 3	1000 / 1050 / 1138	1063	7	No. 5	1350 / 1281 / 1375	1335	4	
" 11	35	7	No. 4	875 / 869 / 825	856	4	No. 5	1287 / 1288 / 1269	1281	1	Knight, Bevan and Sturgis' Portland Cement.
" 12	35	7	No. 4	869 / 906 / 850	875	4	No. 5	1281 / 1106 / 1363	1250	12	
Mean...	.....	.....	.....	.....	980	5 10/14	.....	.....	1396	7 4/14	
Extreme	.....	.....	.....	.....	.....	12	.....	.....	.....	20	

From table No. I. we find the ratio of strength of briquettes Nos. 2 and 3=

$$936:1020=1:1.09 \qquad (1)$$

all setting without pressure.

From table IV. we have the ratio

$$980:1396=1:1.42 \qquad (2)$$

Combining ratios (1) and (2) we have

$$\frac{1.42}{1.09}=1.30$$

Showing that the application of the pressure to the mortar while setting increased its strength about 30 per cent. There is no improvement, however, in uniformity.

TABLE V

Comparative strength of briquettes made in Mould No. 3 with those made in Mould No. 4, all having set under a pressure of 32 lbs. per square inch.

When Made.	Composition		Mould No. 3.				Mould No. 4.				
	Cement.	Water.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	
1879.											
Jan. 25	35	6¾	No. 5	1487 1488 1450	147.	2	No. 6	1288 1437 1325	1350	6	O. F. Alsen & Co.'s Portland Cement.
" 27	35	6¾	No. 5	1650 1638 1687	1658	2	No. 6	1462 1388 1494	1448	5	
" 30	35	7½	No. 5	1375 1412 1125	1304	14	No. 6	1100 1231	1166	6	
Feb. 1	35	7½	No. 5	1350 1281 1375	1335	4	No. 6	1313 1306 1250	1290	3	
Mean...	.....	.....	.....	.....	1443	5½	.....	.....	1327	5	
Extreme	.....	.....	.....	.....	.....	14	.....	.....	.....	6	

TABLE VI.

Comparative strength of briquettes made in Mould No. 3 with those made in Mould No. 5, all having set under a pressure of 32 lbs. per square inch.

When Made.	Composition		Mould No. 3.				Mould No. 5.				
	Cement.	Water.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	
1879.											
Feb. 11	35	7	No. 5	1287 1288 1269	1281	1	No. 7	1250 1319 1312	1294	3	Knight, Bevan & Sturges' Portland Cement.
" 12	35	7	No. 5	1281 1106 1363	1250	12	No. 7	1431 1288 1250	1323	8	
Mean...	.....	.....	.....	.....	1266	6½	.....	.....	1309	5½	
Extreme	.....	.....	.....	.....	.....	12	.....	.....	.....	8	

The breaks in briquettes of patterns 2, 3 and 4 were central; the breaks in briquettes of pattern 5 were at the shoulder.

After the conclusion of these experiments the moulds No. 2 and clutches No. 4 were sent to Saul Ste. Marie for comparison with mould No. 1 and corresponding clutches.

TABLE VII.

Comparison of Strength of Briquettes of Patterns 1 and 2.

When Made.	Composition		Mould No. 1.				Mould No. 2.			
	Cement.	Water.	Clutch.	Breaking weight lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.
1879.										
Mch. 8	32	7	No. 2	1038 1159 1322	1173	13	No. 4	940 875 956	927	6
" 9	32	7	No. 2	1046 1249 1123	1139	10	No. 4	1008 987 979	991	2
" 10	32	7	No. 1	1157 1164 1195	1172	2	No. 4	794 872 811	826	6
" 11	32	7	No. 1	1268 1397 1462	1376	8	No. 4	903 1018 995	972	7
" 11	32	7	No. 1	1414 1246 1191	1284	10	No. 4	984 983 970	979	1
" 15	32	7	No. 1	1288 1252 1300	1282	2	No. 4	832 816 840	829	2
" 17	32	7	No. 1	1251 1251 1145	1217	6	No. 4	913 763 859	845	10
" 18	32	6	No. 1	1502 1518 1673	1564	7	No. 4	945 984 966	965	2
" 19	32	7	No. 1	1411 1218 1322	1317	8	No. 4	948 944 904	932	3
" 19	32	7	No. 1	1370 1317 1384	1357	3	No. 4	843 887 887	872	3
" 20	32	7	No. 1	1339 1326 1389	1351	3	No. 4	790 766 893	816	9
" 21	32	7	No. 1	1283 1206 1254	1248	3	No. 4	816 855 761	811	6
Apl. 21	35	7	No. 1	1531 1227 1363	1374	11	No. 4	847 893 856	865	3
" 23	35	7	No. 1	1203 1329 1155	1229	8	No. 4	857 927 898	894	4

Knight, Bevan & Sturges, Portland Cement.

TABLE VII.—*Continued.*

Comparison of Strength of Briquettes of Patterns 1 and 2.

When Made.	Composition		Mould No. 1.				Mould No. 2.				Knight, Bevan & Sturges' Portland Cement.
	Cement.	Water.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	
1879.											
" 26	35	7	No. 1	961 1107 1114	1061	9	No. 4	756 816 772	781	4	
" 28	35	7	No. 1	1101 1118 1169	1129	4	No. 4	796 884 892	857	7	
" 29	35	7	No. 1	1347 1275 1234	1285	5	No. 4	903 934 957	931	3	
" 29	35	7	No. 1	1279 1317 1288	1295	2	No. 4	856 835 860	850	2	
Mean...	.....	.....	.....	.....	1270	$6\frac{1}{3}$	.....	.....	886	$4\frac{2}{3}$	.....
Extreme	.....	.....	.....	.....	.....	13	.....	.....	.....	10	.....

$$\frac{1270}{886} = 1.43.$$

Table VII. shows that briquettes of pattern 2, broken with clutch No. 4, did not develop the full strength of the cement; in order to learn whether this was due to the clutch or to the form of the briquette, the tests recorded in the following table were made. All the briquettes were made in moulds No. 2.

TABLE VIII.

When Made.	Composition		Mould No. 2.				Mould No. 2.				
	Cement.	Water.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	Clutch.	Breaking weight, lbs.	Mean breaking weight, lbs.	Variation of breaking weight from mean, per cent.	
1879.											
May 5	35	7	No. 1	885 1104 969	986	12	No. 4	779 778 788	782	1	Knight, Bevan & Sturges' Portland Cement.
" 5	35	7	No. 1	858 853 986	899	10	No. 4	890 825 829	848	5	
" 6	35	7	No. 1	1088 932 1010	1010	8	No. 4	918 914 948	927	2	
" 6	35	7	No. 1	1031 893 944	956	8	No. 4	912 893 840	882	5	
" 7	35	7	No. 1	1086 1070 1059	1072	1	No. 4	955 897 1003	952	6	
" 8	35	7	No. 1	1249 1190 1128	1189	5	No. 4	909 1112 1008	1010	10	
" 9	35	7	No. 1	1131 932 961	1008	12	No. 4	994 982 1062	1013	5	
" 10	35	7	No. 1	1125 1036 1262	1141	11	No. 4	1035 992 899	975	8	
Mean...	.....	.....	.....	.....	1033	8¼	.....	.....	924	5¼	.....
Extreme	.....	.....	.....	.....	.....	12	.....	.....	.....	10	.....

$$\frac{1033}{924} = 1.12.$$

Comparing the ratios deduced from tables VII and VIII, it appears that mould No. 1 gives results about 30 per cent. higher than those obtained from No. 2.

In his recent work on Portland cement Mr. Henry Reed refers with some asperity to those who have used forms of moulds differing from the one originally recommended by him to the Metropolitan Board of

Works ; but it appears from his pages that he also has indulged in the reprehensible practice of innovating.

At this time, when no particular form of mould is in general use, no valid objection can be made to such experiments and variations as may lead finally to the selection of a form which will give, with the same cement, uniform results, and, at the same time develop its full strength; then, uniform conditions being observed, the results obtained by one experimenter may be of value to another for comparison.

None of the forms of moulds and clutches which I have used fill both of these requirements. The apparatus giving the most uniform results develops the least strength.

These experiments are submitted to the Society, because they show that with a proper apparatus much higher results may be obtained from a given quality of cement than those heretofore reported; that the form of apparatus affects these results in a much higher degree than is generally supposed, and because I believed that although not successful in attaining the object sought, a report of my failures would not be without interest to those who have become interested in testing cement.

Discussion by D. J. Whittemore.

Mr. Noble shows the necessity of having a standard form of mould and clutch for tensile tests of cement. Mr. Maclay has shown the necessity of uniformity of exposure of the samples, effect of temperature, etc. Mr. Noble and others have shown the effect of pressure in moulding ; all indicating that to accumulate data comparable, each experimenter should observe similar conditions of manipulation, exposure, and testing, having similar forms of samples, and other like conditions unnecessary at present to mention.

In the matter of tensile strength of cement, it has been, and is still my belief that that form of briquette and clutch which would most nearly indicate the actual tensile strength, should give the most uniform results. The want of uniformity in testing with the ordinary form led me, some years ago, to devise a form essentially the same as No. 3 used by Mr. Noble, and the resulting tests from it were generally high, but had a sad want of uniformity until I discarded the use of rubber rings between the bearing surfaces of the briquette and cup-clutch, after which

the percentage of discrepancies was reduced to about the same in the use of my modified form of the common briquette.

My observations lead me to believe that the injurious effect of rubber so used, lies in the fact that its extreme adhesive power does not permit the cup-clasps to take their exact proper position under strain. It is very difficult, if not impracticable, to set the two clutches and briquette by the unaided eye, so that the line of strain shall be axial throughout, and if this is not done excessive strains will be generated in an extreme part of the section of briquette, resulting in discordant determinations. Without rubber intervening, my experience is that the parts adjust themselves to the line of strain more easily and perfectly. I trust that Mr. Noble will give form No. 3 a further trial without the use of rubber-bearing surfaces. It would, perhaps, be unfair for me to imply or assert that from the causes mentioned arises the excessive percentage of variation shown by Mr. Noble in the use of Form No. 3. I only state my experience with it, and know not what expedient he adopted to overcome the difficulty mentioned.

I am of the opinion that a decidedly better form of cylindrical briquette can be made, one that will in a great degree overcome this difficulty, and the form I have devised for this purpose is shown in the accompanying sketch, Plate No. III., which shows also the cup-clutch in section. This form of briquette has at each end a spherical enlargement fitting cup-clutches, at the bearing surfaces, like the ball and socket joint—not cone-shaped, as in form No. 3. By lubricating the bearing surfaces of the clutch the briquette will adjust itself easily, when under strain, to its proper position. The circular briquette permits moulding and setting of cement under definite pressure without changing the breaking section, a quality not possessed by the usual form.

The accompanying sketch is full size for briquettes having a breaking area of one square inch, which, though less than the usual size, is, in my opinion, large enough for the purposes desired. The amount of cement required by this size is consequently but a fraction of that generally used, which is a great desideratum with those experimenters who are required to prepare the cement from the native rock by crucible burning, and grinding with mortar and pestle. It is my intention to experiment with this form the coming winter, and report to this Society the evidence deduced.

Except for critical work I have extensively used my modified form of

Briquette & Cup Clutch

Designed by

O. J. Whittemore

Explanation

A & B forms the Cup-Clutch and should be made of Sun Metal or Soft Steel

C. Briquette

D Brass Rings for holding the two halves of Cup Clutch B in place

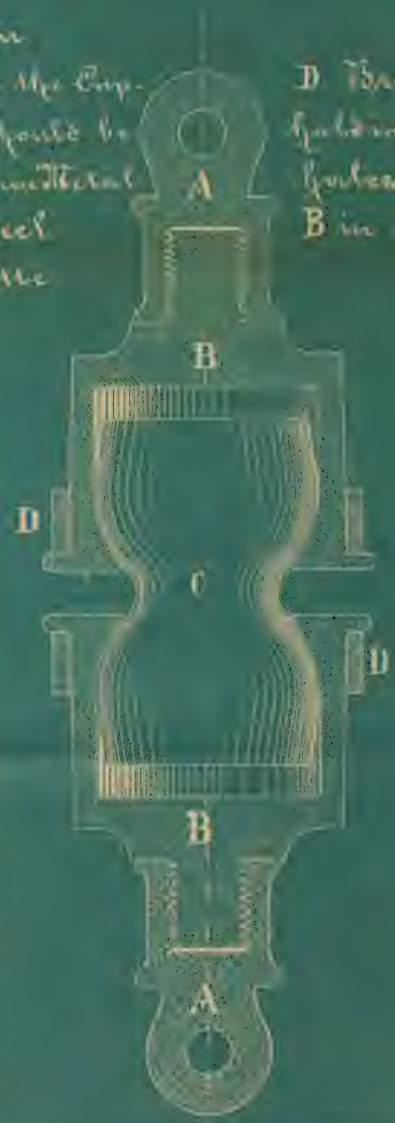

PLATE
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. LIII.
WHITTEMORE
ON
BRIQUETTE CUP CLUTCH

Combined Clutch and Mold

designed and used by

O. J. Whittemore

for manufacturing Common Brick

Scale

Full Size

A

B

C

PLATE IV.

TRANS. AM. SOC. CIV. ENGRS.

WHITTEMORE ON

the common briquette shown in the sketch, Plate No. IV. In this form the mould is transformed into the clutch by simply removing the screw bolts B, B, and the fillers, C, C, In moulding, these parts are in place, and the moulded sample is not removed by pressure but by loosening the screw bolts A, A, allowing the mould to be separated longitudinally, and the moulded briquette to pass out easily. In testing, care is taken to introduce the test sample between the corresponding parts of clutch in which it was moulded, thus insuring a perfect fit.

It may not be out of place for me to express the opinion that undue value is placed on experiments, as heretofore conducted, in ascertaining the tensile strength of cements to the exclusion of nearly all other tests. In my opinion, one of the most satisfactory tests of the value of this material, is that so largely employed by Gen. Gillmore in accumulating data for his work on "Limes and Hydraulic Cements," to wit: that of subjecting specimens moulded in the form of parallel opipedons, to transverse stress.

I again suggest that it is eminently proper for this Society to recommend a code of rules for testing cements. I feel that not one of its members would fail in an endeavor to comply with such reasonable rules as would probably be suggested, and that in the course of a short time, by a close observance of such rules, and availing ourselves of the experience already gained, both at home and abroad, we shall accumulate comparable data from which to more understandingly judge of the strength and value of this wonderful production.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

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CXCIII.

(Vol. IX.—May, 1880.)

DESIGN AND CONSTRUCTION TABLE FOR EGG-SHAPED SEWERS.

By C. G. Force, Jr., C. E., Member of the Society.

Read at the Eleventh Annual Convention, June 17, 1879.

The design for the cross-section of the first brick-sewers constructed in Cleveland (except for steep grades) was substantially the usual egg-shaped section common in England and in this country. The arch is a semicircle, consequently the greatest breadth of the section is at the spring-line. The vertical diameter is one and one-half times the transverse diameter; hence the spring-line of the arch is two-thirds of the vertical diameter above the base of the section. The *radii* of the side arcs are equal to the vertical diameter, and the radius of the lower arc is one-fourth of the transverse diameter of the section. The curvature of the side arcs is, therefore, slight.

In the construction of brick-sewers in Cleveland, in accordance with this design, great difficulty was experienced in holding the invert and side walls in proper shape until the arch could be completed and loaded, and failures had occurred in completed work by buckling in of the side

walls immediately below the spring line of the arch from the lateral pressure of the quicksand and water which underlie the city, and are constantly met with at the depth the sewers are built. These failures occurred in sewers of the dimensions of 6x4 feet, with 8-inch walls of brick, laid in hydraulic cement, and without headers, except one course at the spring-line of the arch, in cuttings, from 12 to 15 feet in depth. The brick invert was laid in a plank invert held in shape by curved ribs cut from plank and planed inside.

Taking these facts, and estimates made at the time, as a basis, it was deemed impracticable to construct brick sewers larger than 4½x3 feet with this form of section through material of the character met with in Cleveland without a specially prepared foundation, or a thickness of walls disproportionate to the size of the sewer when in comparatively dry cuttings, and consequent disproportionate increase of cost.

The difficulties in construction, referred to above, were obviated, and the stability of the completed work insured, without materially decreasing the carrying qualities of the sewers, subject to an intermittent flow, by the adoption of the form of section shown on Plate V., Fig. I.* The construction is as follows: Describe the circle *C B D* and make the arcs *B E* and *D E* each equal to one-sixth of the circumference, and the arcs *B C* and *D C* each equal to two-sixths of the circumference. Through the points *B* and *C*, *D* and *C*, *B* and *E*, *D* and *E*, draw the indefinite straight lines *B F*, *D G*, *D H*, and *B K*, respectively, and with the point *C* as centre, and a radius equal to the radius of the circle, describe the arc *F G*, and with the points *B*, *D* and *E* as centres, and the *radii B F*, *D G*, and *E H*, describe the arcs *F K*, *G H*, and *H K*, respectively.

It will be observed that in this cross-section the spring-line of the arch is nearly identical with a horizontal line passing through the middle point of the vertical diameter; therefore, in the construction of sewers with this form as compared with the usual egg-shaped section in which the spring-line is two-thirds of the height above the base, the amount of brickwork laid upon the centering is proportionately larger, and the more expensive, and usually most neglected portion of the work, is proportionately less, and at the same time the *height* of the side walls to be held in position until the arch can be loaded, referred to above, is very

* Designed by the writer.

materially decreased, a matter of considerable moment in the construction of large sewers through bad ground.

As to the necessary thickness of walls for this design, the practice is to have for sewers not larger than 6 x 4½ feet, 8-inch walls, in cuttings from 14 to 18 feet in depth, and 12-inch walls, for sewers from 6 x 4½ feet to 7¾ x 6 feet, in cuttings from 16 to 22 feet in depth, using a plank invert only for a foundation, thus showing the expediency of the adoption of a form of cross-section more nearly approaching a circle, as compared with the usual egg-shaped section for sewers with ordinarily imposed conditions, in localities where the material through which they are to be constructed is, or is liable to be, surcharged with water.

Fig. II, Plate V., shows the same design as Fig. I, and will assist in the analysis of the calculations and the application of the following :

Let R = Radius of lower arc of 60°.
" A = Area of section.
" C = Circumference.
$\pi = 3.1416$.

$$\text{Then } A = R^2 \left[\pi \left(3.1666.. + \sqrt{3}\right) - \sqrt{3} \right]$$

$$C = \frac{\pi R}{3} (4 + 5\sqrt{3})$$

Vertical diameter $= R(3 + \sqrt{3})$
Transverse " $= R(2 + \sqrt{3})$

Taking $R = 1$ in the above formulæ.

$$\text{Then } A = \pi \left(3.1666.. + \sqrt{3}\right) - \sqrt{3} = 13.6577.$$

$$C = \frac{\pi}{3} (4 + 5\sqrt{3}) = 13.2581.$$

Vertical diameter $= 3 + \sqrt{3} = 4.7321$.
Transverse " $= 2 + \sqrt{3} = 3.7321$.
And the area of *any* section $= 13.6577.. R^2$.

The following table shows a series of sizes for brick sewers, No. 1* to No. 16 inclusive, adopted by the City of Cleveland, and is here given as an illustration of a convenient method of notation in connection with a series of areas which in practice fulfills the requirements of ordinary city and town sewerage, taking a "foot" as the unit of area.

The areas A, in the second column, are derived from assumed con-

* Not used.

PLATE V.
TRANS. AM. SOC. CIV. ENGRS
VOL. IX Nº CXCIII
FORCE
ON EGG SHAPED SEWERS.

secutive numbers N, in first column, and are equal to $\sqrt[3]{N^4}$, N denoting size as, size No. 1, &c.

The vertical and transverse diameters are given in units corresponding to the unit of area.

Assumed consecutive number denoting size. $= N$.	Sectional Area. $= \sqrt[3]{N^4} = A$.	Radius of lower Arc of 60° $= R$.	Vertical Diameter.	Transverse Diameter.
1.....	1.0000	0.2706	1.2805	1.0098
2.....	2.5198	0.4295	2.0326	1.6031
3.....	4.3268	0.5629	2.6634	2.1006
4.....	6.3496	0.6818	3.2265	2.5447
5.....	8.5499	0.7912	3.7441	2.9528
6.....	10.9027	0.8935	4.2279	3.3345
7.....	13.3905	0.9902	4.6855	3.6953
8.....	16.0000	1.0824	5.1218	4.0394
9.....	18.7208	1.1708	5.5402	4.3694
10.....	21.5443	1.2560	5.9433	4.6873
11.....	24.4638	1.3384	6.3332	4.9948
12.....	27.4731	1.4183	6.7114	5.2931
13.....	30.5674	1.4960	7.0793	5.5833
14.....	33.7420	1.5718	7.4378	5.8660
15.....	36.9932	1.6458	7.7879	6.1421
16.....	40.3175	1.7181	8.1303	6.4122

The areas A in the second column are based upon assumed consecutive numbers N, denoting size, in the first column, and are $A = \sqrt[3]{N^4}$

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CXCIV.

(Vol. IX.—May, 1880.)

THE PRESERVATION OF TIMBER.

By J. W. PUTNAM, Associate A. S. C. E.

READ OCTOBER 15TH, 1879.

In January, 1869, work was commenced on the construction of a line of railroad between New Orleans and Mobile. The road extends for nearly fifty miles through a flat, marshy country, crossing various streams and bayous, which are at certain seasons of the year tidal and infested by the *Teredo Navalis*. From thence to Mobile it passes

through a higher sandy country, crossing several tributaries to and arms of the Gulf, also salt, in which the ravages of the *teredo* are very great. The bridges over all the water-ways were constructed on pile foundations. Yellow pine was generally though not always used for piles, and driven soon after being cut. During the months of May and June, 1869, a part of the piles were driven for the bridge across Bay St. Louis, a sheet of salt water two miles wide, and the work was then suspended until the following fall and winter, when the bridge was completed. During the succeeding November, or in less than nine months from the completion of the bridge, the piles began to give way and break off, being thoroughly honeycombed. A few weeks later the piles began to break in the bridge over Bay Biloxi—a bridge one and one-fourth miles long—and during the month of April following it broke down, letting an engine and four freight cars into the bay. The work of rebuilding was begun during the winter of 1870 and 1871, or within two years of the time of turning the first shovelful of earth in the construction of the road. The Bay St. Louis bridge was built on piles sheathed with yellow metal, and the Biloxi bridge on piles sheathed with zinc. The piles were hewn to one foot diameter, covered with a layer of felt, and then with the metal, the whole being securely nailed. The other bridges were not entirely rebuilt at that time, but had new piles driven underneath, and sprung into position. In the Pascagoula and Pearl rivers—streams from twenty to fifty feet deep, and having very strong currents during the spring floods—piles were perforated by the teredo from within five or six feet of the surface of the water to the bottom, and some of them were found to be cut completely off. The sheathing was found to be an efficient protection for the piles as long as it remained intact, but the waters of these harbors were found to contain something which, uniting with both kinds of metal, dissolved and rendered them worthless in a few years. The yellow metal lasted about twice as long as the zinc.

With the great number of bridges subject to the attacks of the *Teredo Navalis* the contest was now seen to be one of life or death.

The *Teredo Navalis* is an inhabitant of salt or brackish waters and lives within timber, the most of which has been carried out to sea by rivers. Hence, it is not probable that it would inhabit the waters of a rainless coast.

It is of a translucent and jelly-like consistence, varying in size from

a creature invisible to the naked eye to one, two, or more feet in length, with a diameter of five-eighths of an inch. I have been informed that specimens one inch in diameter and four feet long have been taken from the planking of ships.

It seems to grow about two inches in length a month, and appears to live from eight to sixteen months. Between March and May the greater part of the old ones disappear. The young make their appearance in March, but do not become abundant until May, and continue to develop until November. It is a solitary animal, living in a cell alone, and having no communication with its fellows. It is probably hermaphrodite, and like other low forms of life, is very prolific, a single one depositing from one to three million eggs in a season. The eggs, I think, are only hatched by the action of salt water, as no young appear when the water is fresh by reason of rain. The eggs have been supposed to hatch within a week of their deposition in water, but I think they often remain much longer, and perhaps some of them pass the entire winter afloat. Having been hatched, they swim about in search of food, and in this condition millions of them must be carried out to sea by ebbing tides and distributed to other ports, or perish by starvation.

If they come in contact with timber which suits their taste, they attach themselves by a foot or sucker and enter, making their way by means of a pair of forceps-like cutters. The cutters are a pair of concave or partly spherical shells placed on each side of the head, and extending partly over it. They are joined by a hinge-like joint at one end and free at the other, and are moved by a firm, strong muscle, which is attached to the lower edge. In the center of the head and between the free edges of the cutters is a firm muscular foot or sucker, by which the animal holds itself in position for work. Beneath the free ends of the cutters is the mouth or orifice leading to the stomach, to which further reference will be made.

The hole cut for entrance is very minute, so small as to be seen only by the closest observation. Having entered the timber and begun to feed, they enlarge rapidly. The cavity cut is lined with a shelly deposit of carbonate of lime, to which the animal is attached near the point of entrance by a muscular coat and the skin, shutting out all water except that taken through canals in the body for respiration and lime. At the tail are two oar-shaped bones or shells, the blades of which are ribbed like a file, the long, round ends extending inside the body. By means

of the muscular coat attached to the lining shell it is enabled to project these file-like bones outside the timber, thus removing obstructions, maintaining communication with the water, and enlarging the orifice to meet the increasing demands of the growing animal. It may also serve as a protection against the depredations of other animals by closing the orifice and presenting a front of solid lime. In fact, I do not see how any animal can attack it without first being able to tear down its armament. Should an entrance be attempted while the bones are drawn in, at the first alarm they would be forced out, and being tapering, the intruder would find himself in a vice-like trap from which it would be difficult to escape.

In the operation of feeding, the teredo places its foot or sucker against the wood. The two muscles move the cutters like a pair of forceps or scrapers. The chips are carried to the orifice or mouth before referred to, and thence to the stomach. Open an animal freshly taken from the water, press the stomach, and the contents will flow out through the mouth. Place these under a powerful microscope, and the cuttings are plainly discernible.

The stomach is a brown, oblong sac a little below the head. From its lower end extends a long intestine or alimentary canal. This passes about one-fourth the length of the animal downwards, and turning in a loop, passes back to the head, where it forms another loop beneath the foot or sucker, and then passing downwards the entire length of the animal, discharges at the orifice between the two file-like bones at the tail. This connection may be traced in some of the specimens exhibited to the Society. From this it will be seen that the teredo cuts timber for food, and not as a burrow. I have also noticed that on coming in contact with timber not suitable it retracts one-fourth, more or less, of its length, and abandoning its old cell, cuts a branch in another direction, always taking care to build a large dam or wall across the entrance to the abandoned cell. I have seen three different branches cut by the same animal.

I do not see why the teredo has generally been supposed to cut with a rotary motion. Any one who will take the trouble to sharpen the end of a pipe, and place in the center a soft, elastic point, and revolve the pipe forward and back will see the value of such a cutter.

Beside the canal or duct mentioned there are others, extending from the vital organs to the orifice, which I have not traced out and exam-

ined as thoroughly as desirable. The ovary is a large gland situated between the stomach and first loop in the intestine. It becomes enlarged and active in the winter and early spring in animals which have attained any considerable size. I have reached no satisfactory conclusion on the subject of their reproduction, and will only give a brief *resume* of observations.

Early in March a few animals may be found which have just entered the timber. As the season progresses the number which have just entered increases until the first of October. From that time the number decreases rapidly until the last of November. Through December and January I find none. Having entered the timber they grow in length about two inches a month. In February and March the largest animals are found. I have taken them out measuring twenty-three inches, and large numbers can be found at this season from fifteen to eighteen inches in length, with the ovary so filled with eggs that the smallest part pressed between two glasses in a microscope magnifying three hundred and fifty diameters will show from thirty to a hundred in a single field. I have estimated that a single ovary would contain three million eggs. During April the large animals all disappear, and only the smaller ones up to four or six inches in length remain.

I do not think clear fresh water necessarily destructive to them, as I have seen the water of the bays along the coast fresh enough for good drinking purposes by reason of heavy and continual rains for two or three months, and yet they appeared healthy and vigorous. I have reliable information that vessels have been taken up the Mississippi river to New Orleans—over a hundred miles—during the low stage of the river, when but little sediment was carried, and tied up for the purpose of killing the worms; but when placed in the dry docks two or three months later the worms were found to be in an unprofitably healthy and vigorous condition. If the water be roily, or loaded with silt from heavy rains, it will probably destroy them. During heavy rains, and while the water is fresh, I have not found young animals entering timber, and have supposed that the eggs are only hatched by the action of salt water, as some seeds will only germinate under peculiar conditions.

It has been supposed that the teredo leaves the timber in search of other fields. This probably comes from the sudden disappearance of large numbers in the spring. As they are attached to the shell so firmly as to exclude the entrance of water, they can no more leave it than can

the oyster its shell. Having fulfilled their mission they die, and from their soft, boneless construction they rapidly decompose, and are washed away, leaving only their shell and cutters.

The rapid destruction of timber in exposed situations by decay, and the ravages of land and marine animals, have led people in every age to devise measures to prevent such waste of time and means, and render their works more enduring. The Egyptians—famous for their work in stone —buried their kings in coffins of wood that will endure until those grand old pyramids shall crumble to dust. They saturated their planks with what appears to have been a hydro-carbon or asphaltic oil, and they have stood the test of the few thousand years that have passed since they were prepared.

Modern investigators have ploughed a wide field in search of something which would be equally effective and comparatively inexpensive. Hundreds of patents have been secured, and, with a flourish of trumpets, some have been put to use, only to run a brief race and quietly subside.

Perhaps the only preparation that has stood the test is a hydro-carbon, a product of the destructive distillation of coal. About the year 1835 experiments were begun with this product, usually called creosote or dead oil. It is rich in phenols, but its greatest ingredient is naphthaline. In the scramble for work, and from a mistaken idea that cheapness of construction is economy, as well as by errors of judgment, much defective work has been done. In some cases such work has given partial satisfaction by increased length of service, while in others the additional outlay has been entirely thrown away, bringing disrepute upon all classes of creosoted timber.

Certain rules have been adopted by engineers in the selection and use of timber, which, while valuable in the use of untreated timber, should be set aside in the use of creosoted material. For instance, in ordinary timber-work for exposed situations, compact, solid heart timber is usually specified, and the cutting and framing, more or less, done on the ground.

Such timber, if treated, will prove difficult to saturate. The soft and unripened growth, or sap-wood, more readily absorbs oil, and becomes the more durable. I am satisfied that the more porous and destructible classes of timber now considered nearly worthless, will, when creosoted, become the most valuable. Fir, swamp ash, and old field pine, when treated, will outlast the best white oak, yellow pine, or cedar uncreosoted. In ordinary use the heart of yellow pine will more

than six times outlast the sap-wood. I have at West Pascagoula pieces of yellow pine, the sap-wood of which was partially saturated with creosote oil in October and November, 1872, and which since then have been exposed to contact with the earth, and unfavorable climatic conditions. Such parts as received oil are as perfectly sound as when cut from the stump, while the untreated sap, and a considerable part of the heart, are entirely rotten.

Timber which, untreated, would decay in one season, will remain in closely packed piles or on the ground, in the most unfavorable conditions, perfectly sound for years.

As far as practicable all cutting and framing of timber should be done before treatment, except in open, porous timber, which has been thoroughly saturated. Holes for bolts may be made if they are fitted so as to exclude water. Ordinary building timber will not be thoroughly saturated, and too much care cannot be taken in this respect.

From what I have seen of creosoting, I consider timber which has been saturated with coal-tar oil practically indestructible, and as durable as iron or stone. There is a property in the oil which prevents fermentation and the change which we call decay. How much oil per cubic foot of timber is necessary to produce this result I have not determined. If a small quantity—say five to ten pounds per cubic foot—could be evenly distributed through the stick, it might be sufficient. But as the oil first comes in contact with the outside of the timber the central part will receive none until the outside has become thoroughly saturated. No method is known by which a given quantity of oil less than the total amount which would be absorbed by timber can be so distributed as to reach every part. The amount which can be forced into timber varies from eight to forty pounds per cubic foot. This last amount can only be forced into very light and porous timber.

The unequal results from creosoting timber probably come from the unequal distribution of the oil.

"Of the ties that were treated with creosote oil and laid on the Great Eastern Railroad in England in 1841 eighty per cent. were still doing service in 1862, a period of twenty-one years."

No statement is made as to whether the ties that failed had been thoroughly treated or not. A close examination and report of such con-

ditions would greatly enlighten the public as to the actual value of different kinds of timber and the process of creosoting.

As a defense against the ravages of the *Teredo Navalis*, or ship worm, I think coal-tar oil is invulnerable. It is deadly to cold-blooded animals. A small quantity stirred in a pool where there are fish will kill them. I have placed pieces of treated timber in water where the worms were abundant, and though rapidly entering other timber they would not touch that which had been creosoted.

I have taken pieces of timber, and saturating a part of each one, have left the remainder free from oil. The teredo would enter and destroy the untreated parts, and perish for want of food, leaving the treated parts perfectly good. Wherever it came in contact with the creosoted wood it turned away.

A piece of creosoted plank was inserted in the bottom of a skiff. When the untreated part of the skiff was honeycombed and worthless the treated plank had not been touched.

The bottoms of boats may be protected by drying them and applying what creosote they will absorb.

Water does not unite with the oil, consequently the oil remains in the timber an indefinite length of time.

If this oil be poured in a running stream it will roll along the bottom like molten lead or quicksilver.

A large number of reports on the subject of creosoting, by civil engineers in Europe, have been published during the last fifteen or twenty years, bearing witness to the value of coal-tar oil for the protection of timber against the ravages of land and marine animals. Where the work of creosoting has been properly done piles have stood thirty and forty years, and are still good. Untreated timber, in the same places, would only have stood from two to six years.

From the difficulty of submarine examinations the faithful, thorough creosoting of submerged timber is of more importance, if possible, than where prevention of decay alone is desired.

The trustees for the bondholders of the New Orleans & Mobile Railroad had become so thoroughly convinced of the value of coal-tar oil as a preventive of decay in timber—which takes places rapidly in the long,

warm seasons of that latitude, and of the ravages of the teredo, which is abundant and destructive to the numerous and long bridges which cross the bays and inlets along their line—that they decided in the winter of 1874–5 to creosote the piles and timber used in bridge construction. As no works could be found in this country treating timber thoroughly enough to be satisfactory, it was thought advisable to build machinery and do the work on a plan different from any then in operation. Accordingly, works were erected at West Pascagoula, Miss., at a cost of about fifty thousand dollars, and all the bridges and waterways on the road have been constructed of creosoted timber, except the long spans of trusses, which are of iron.

The work has been eminently satisfactory. Pile piers have been built which bid fair to outlast their iron superstructure.

These works contain two reservoir tanks for storing oil, placed in the ground; two tanks for treating timber, six feet diameter inside by one hundred feet long; a large tubular condenser and pump for supplying it with water, a large vacuum pump, an oil pump, a powerful force pump, a hoisting engine for handling timber, a pair of boilers capable of furnishing the required steam, and a super-heater. These are all connected by the requisite pipes and valves.

Each treating tank contains nearly five thousand feet of one-inch pipe arranged in coils, through which super-heated steam is passed for seasoning timber, and also iron rails upon which cars loaded with timber are moved in and out. Both heads of the treating-tanks are moveable. At suitable distances are transfer-derricks for loading and unloading timber. A large number of piles, ninety and ninety-five feet long, have been handled with them.

In work, piles are cleaned of dirt and bark, butted and sharpened, and timber cut and framed ready to be put in position. It is then loaded on iron cars, built for the purpose, and hauled into the tank.

Steam is then turned in through a perforated pipe extending along the inside at the bottom of the tank.

This is continued until the timber has become heated through. The vapor is then condensed, and a partial vacuum produced. Super-heated steam is passed continually through the coils of pipe to vaporize the sap and moisture contained in the timber, and as fast as vaporized it is con-

densed. A partial vacuum being maintained, the moisture vaporizes at a low temperature, and the seasoning proceeds rapidly.

When the timber has become properly seasoned the tank is filled with oil and a pressure applied by means of the pressure-pump of from one hundred and fifty to two hundred pounds per square inch. This pressure is maintained until the pressure-gauge remains constant, showing that the timber will absorb no more oil.

The oil is then drawn off, the load drawn out, and another load which has meanwhile been prepared drawn in and the process repeated.

The consumption of oil by this process has usually been from twelve to eighteen pounds per cubic foot, or from one and one-fourth gallons to two gallons per cubic foot.

Over three gallons per cubic foot have been injected in some loads.

The main features of our plan of treatment are the extraction of the sap or moisture in the timber to prevent fermentation, and also to provide room for oil. Timber can no more be steamed dry than it could be seasoned by boiling. The timber, being cooler than steam, would condense and absorb it, thus accumulating moisture. Water cannot be drawn out of timber by a vacuum alone. If timber retained its moisture by atmospheric pressure, then by removing such pressure it would flow out. But moisture is retained in timber by capillary attraction, which is left in full force when atmospheric pressure is removed. We steam timber to heat it through as being the simplest method of conveying heat; then condense the steam and pump out the air to produce a partial vacuum.

It is well known that water vaporizes in a vacuum at a low temperature. While under pressure the degree of heat at which it vaporizes rises to correspond with the pressure applied. By maintaining a partial vacuum we are enabled to vaporize the moisture rapidly, and at a temperature which will not injure the timber. When the pressure is removed by condensation, the heat absorbed by the timber during the steaming expands the moisture by vaporizing and drives it out. Superheated steam is passed through the coils of one-inch pipe in the treating-tank to maintain the temperature and assist in vaporizing the moisture, and as fast as vaporized the moisture is drawn away by the condenser.

This process is continued until the timber has become satisfactorily

seasoned, when the tank is filled with oil and a pressure of from one hundred and fifty to two hundred pounds per square inch is applied until the timber will absorb no more oil.

It is now nearly four years since the construction of bridges with creosoted timbers was commenced, and during that time not a fire has caught in the new work from passing trains, while on bridges constructed of uncreosoted timber watchmen were a continual necessity. In this respect we are happily disappointed.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CXCV.

(Vol. IX.—June, 1880.)

ANNUAL ADDRESS, 1880.

Read at the Twelfth Annual Convention of the Society held at St. Louis, Mo., May 25th, 1880.

ENGINEERING PROGRESS IN THE UNITED STATES.

NOTE.—The President being unable to deliver the Annual Address in consequence of his journey to Europe, it has, at his request, been prepared by Mr. O. CHANUTE, Vice-President, with the assistance of members of the Society.

It has sometimes been said that, when in after centuries historians write of the period in which we now live, they will probably characterize

it as the age of material and mechanical development; as the time when man fairly entered upon the mastery of the earth upon which he lives.

We are in, and part of the movement, and perhaps we cannot well be judges over ourselves, but we can realize at least that, while various periods have been marked by human activity in other directions, from the end of the eighteenth century dates the time when man began to utilize, on a large scale, the powers of nature, and to make our world a more comfortable abiding place for its inhabitants. That since the steam engine came to increase, more than tenfold, the productive forces of men, we have entered upon a period of enormous producing and cheapening of all the necessities, and of many of what used to be considered the superfluities of life.

Brought forward by the requirements of this utilitarian movement, the engineer has become one of its most important agents. To him, as a trained constructor and scientific mechanic, is entrusted the task of executing the works by means of which the cost of production and of distribution are cheapened. His business is to design and to superintend required improvements, to invent or to bring into practical use labor and time-saving appliances, and his art was well defined by Telford, in the constitution of the British Institution of Civil Engineers as, "the art of directing the great sources of power in nature, for the use "and convenience of man."

We seldom realize how very young is our profession. From the earliest historical periods, until within about two hundred years, construction, practically, was in the hands of architects. They built pyramids, temples, roads, fortifications, and such weak machines as they could work by hand, but it is only in modern times that a special body of men has devoted itself exclusively to the building of works and machines for utilitarian purposes; to the emancipation from toil of the "hewer of wood and the drawer of water."

So recently as two hundred years ago, when the English people began the works which have made them one of the great nations of the earth, there was such a lack of trained constructors in their country, that they were compelled to send to Holland for what were then called "Hydraulic Architects," to direct the reclaiming of their marshes and to inaugurate their canals. Soon, however, they excelled their early teachers, and trained the very able engineers who established the

modern profession, and whose labors led to the invention of the steam engine scarcely a century ago.

We, who cannot remember the time when steam engines were not in common use, can scarcely realize that their introduction was so recent; and yet, it was only in 1778, that James Watt, after struggling for over twenty years to remedy the imperfections of such machines (as invented by others,) finally triumphed over all the mechanical difficulties he encountered, and began the regular manufacture of steam engines.

By this step, an enormous impetus was given to development and invention. Not only did the engineer find himself possessed of an instrument which increased many fold the productive powers of labor, but the use of steam, and the wonders it accomplished, turned men's thoughts to the advantages of machinery and labor saving appliances. Invention followed invention in every field of mechanics, fresh discoveries of natural laws took place, which were quickly applied by the engineer, and he has been able to accomplish more in the past 100 years than had been achieved in the previous ten centuries.

It is my purpose to-night cursorily to pass in review what has been done in this direction in this country. In doing this, I shall touch upon some fields which are as yet scarcely recognized here as within the province of the engineer, but which are falling into his hands in other countries, and probably will in this. I think you will agree with me, that starting as an independent nation about a century ago, with a population of some 3,000,000 thinly scattered, and with next to no capital, the modern inventions which we have appropriated or made, have enabled us to accomplish very remarkable results.

Water Works.

The first works in America for the supply of water to towns, were constructed by Hans Christopher Christiansen, and put in operation on June 20th, 1754, at the Moravian settlement of Bethlehem, in Pennsylvania.

The water from a spring, which is still used for the supply, was forced by a pump of lignum-vitæ of five inches bore, through hemlock logs into a wooden reservoir.

The same ingenious Dane, eight years later, replaced this rude pump by three iron pumps of four inches bore and eighteen inches stroke, which for many years were the only machinery for water supply on the Continent, and for seventy years furnished the water for Bethlehem.

Among the oldest, if not the very next in date to Bethlehem, is the Morristown, N. J., Water Company, which was incorporated in 1791, and has ever since furnished the town with water collected from the neighboring hills.

The first application of steam to pumping was in Philadelphia, in 1800, when the third steam engine of any considerable size in the United States was erected on the banks of the Schuylkill. It is believed that these works were the first constructed by a municipality. The first cast iron water pipes were laid in Philadelphia in 1804.

New York was first supplied by a company which erected a small pumping engine about 1800.

During the first thirty years of the century several small works were constructed, among others, at Cincinnati, in 1817 ; at Detroit, in 1827 ; at Lynchburgh, in 1828 ; Syracuse, in 1829 ; and Richmond, in 1830. Few of these works exhibited any great advance in engineering. The enlarged works for the supply of Philadelphia by water power, constructed at Fairmount, in 1822, showed however a marked advance, and were for many years regarded as a model of efficient and economical works. The design and execution of the gravity supply works for New York and for Boston, between 1830 and 1840, were such as can not be greatly improved, even at the present day, except in some minor details.

About 1850 the substitution of light wrought iron pipe, lined inside and out with hydraulic cement, for cast iron, at greatly reduced cost, was found to be practicable in many cases, and the formation of companies to manufacture and lay such pipes, introduced a commercial element into the matter of water supply, and led to the construction of many works.

Improved forms of pumping machinery, which performed a fair duty at small expense for construction and maintenance, were designed and their manufacture became a special business.

The careful analysis and investigation employed in the construction of the works for the supply of Brooklyn, between 1850 and 1860, resulted in a more decided advance, in both theoretical and practical science, than had hitherto been made, the effects of which were seen during the succeeding decade in improvements in pipe manufacture, in engine building, in reservoir construction and in maintenance of works.

Between 1860 and 1870, a further impetus to water works construction, was given by the vigorous prosecution of an enterprise for building entire works for direct supply, by pumping into the mains without the intervention of a reservoir. The success attending this enterprise, owing to the small first cost of construction and to shrewd management, created competition, the result of which has been to force the adoption of scientific methods and the employment of skilled engineers, and as a consequence there has been great improvement in the types of machinery and in economical working.

The pumping machinery of large cities has also been greatly improved; the duty now required, and uniformly maintained, being at least fifty per cent. greater than it was thought possible to obtain twenty years ago, or than is now furnished by the less costly "commercial engines," of which two firms alone have built 242 for 168 towns, with an aggregate pumping capacity of 734 millions of gallons per day.

The construction by Mr. Chesbrough of a submarine tunnel for two miles under Lake Michigan, to furnish water for Chicago, was one of the boldest engineering feats of this century. Its successful completion was followed by the construction of several similar works.

On the Pacific coast, the use of unprotected wrought iron pipe for conveying water great distances, and under great pressure, has proved very successful.

During the past ten years, the most important work executed, has been the enlargement of the gravity supply for Boston, by the construction of a conduit of masonry, in the designing and erection of which the latest and most perfect methods have been followed. The subjects to which particular attention has been paid by engineers during this period have been the efficiency of pumping machinery, the capacity of gathering grounds, the preservation of the purity of the water, and the prevention of waste by consumers.

All American works are constructed for a constant supply, and most of those first built had a capacity far in excess of the then demand, which caused the formation of habits of wastefulness, which it has been found difficult to check when the limit of the capacity was nearly reached.

The magnitude of the interests involved in this branch of engineering, may be judged from the fact that there are now in the United States and Canada, 569 towns with a public water supply, having a population of

about twelve millions, to whom there are daily distributed over six hundred millions of gallons of water, through thirteen thousand miles of pipes, of which about ten thousand miles are of cast iron.

About one half of these towns are supplied by gravity, many of them, however, having supplemental pumping power. The total capacity of the pumping engines now in use being about 1 900 millions of gallons per day.

Meanwhile improvements in plumbing and house distribution have greatly added to the convenience about our homes, and we now virtually have a spring of cold, and another of hot water, in almost every room of our city houses, to put on tap at will.

Hydraulics.

The attention of manufacturers was drawn at an early day, to the development of the water power of the streams on the Atlantic coast. With the aid of capitalists who appreciated the value of an investment in experimental researches, some of the most effective efforts, towards the solution of problems in practical hydraulics, have been made by American engineers, on a scale unattempted in Europe.

The early foreign experiments, on which most of the formulæ for the discharge of water from weirs, orifices and pipes are based, were on too small a scale, to furnish data capable of generalization, for greater discharges.

The experiments of Mr. Jas. B. Francis, at Lowell, have among other valuable results, established correct values for the co-efficient of discharge of weirs, and his formula is now generally used.

The researches which have been made at Holyoke and Lawrence, have done much to settle disputed points in relation to the movement and effect of water in channels, and the systematic experiments now in progress, on the new conduit of the Boston Water Works, cannot fail to be of the greatest value in determining the co-efficients of flow in masonry channels.

The laws governing the flow of water in pipes, are still too little understood. It is a reproach to American engineers that so little effort is made to discover them, notwithstanding the opportunities presented by the pipe systems of our water works, sewage systems, and hydraulic mining conduits.

There is required, not only the collation and study of facts, but the generalizing faculty to invent new forms of expression, the existing formulæ, which come nearest to exactness, being too complicated for ordinary use.

In the treatment of the larger hydraulic questions, involving the flow of great rivers and their regulation, American engineers are prominent; both as regards the discussion of theories, and their practical application, and the names of Ellet, Humphreys, Abbot and Ellis, will at once occur to your minds, as those of engineers who have added to our knowledge on this subject.

Canals.

A list of the canals constructed in the United States, foots up 4 840 miles; of these some 300 miles have been abandoned.

The canal still awaits that improvement in its motive power which Stephenson accomplished for the railroad, by the invention of the locomotive; steam is yet to be successfully applied to the propelling of canal-boats. Quite a number of attempts have been made in this direction, but none have come into general use; and the latest of them, the design of Mr. Baxter, which was so favorably looked upon four years ago, and introduced on the Erie Canal, is understood not to have proved a financial success. It is possible that a fresh attempt, in a modified form would succeed better, but for the present attention is being directed to other methods.

The Belgian system is being tried this season, on the ninety-three miles of the Erie Canal between Buffalo and Rochester. This consists, as probably you know, in the laying of a wire rope or chain in the bed of the canal, to be fished up by the boat which wants to use it, and passed around the drum of a winding steam engine placed upon its deck; the working of which pulls the boat along the chain, and thus along the canal. This system has given economical results abroad, but many engineers think it can be improved upon.

The Nestor of our profession in this country, our Honorary member, Mr. John B. Jervis, who at the age of four score, yet preserves his clear intellect, and interest in engineering matters, proposed year before last to supply steam power to the towing of canal-boats, by drawing them with locomotives specially constructed for the purpose, and running upon

railroad tracks, to be laid on each bank of the Erie canal. He calculated that with an expenditure, then estimated by him at $7 524 000, the cost of towing could be reduced from 25.55 cents per mile to 10.50 cents per mile per boat, and that the time of a round trip from Buffalo to Troy and return, would be reduced from 17½ to 13¼ days, or a saving of 4 days, the value of which he estimates at $37 04 per trip.

This should be tried, and it may be that it will allow of much greater speed than now obtains on canals, for I remember reading in an English review, an account of the extraordinary results obtained by Mr. Fairbairn in 1830, in some experiments on the Monkland Canal, which showed that while the resistance to the passage of a boat increased rapidly at a speed of 3 to 8 miles per hour, at a speed of 8 to 14 miles the vessel rose and skimmed over the surface of the water with a very much reduced resistance. But the cost of horse power at high speed opposed the prosecution of this plan on the score of economy, and Fairbairn's design of a light, swift canal-boat has not hitherto been carried out.

Railways.

Quick to appreciate the consequences of the invention of the locomotive, or rather its marvelous improvement by Stephenson in 1829, and the peculiar adaptability of the railroad to our country, as a means of settling up new lands and of cheapening the interchange of products, we began building railways very soon after the English, and have pushed their construction with unexampled vigor.

From advanced sheets kindly furnished by Mr. H. V. Poor, we have the following table of railway construction in the United States in each year since 1830.

STATEMENT SHOWING THE NUMBER OF MILES OF RAILROAD CONSTRUCTED EACH YEAR IN THE UNITED STATES FROM 1830 TO 1879 (DECEMBER 31).

YEAR.	MILES IN OPERATION.	ANNUAL INCREASE OF MILEAGE.	YEAR.	MILES IN OPERATION.	ANNUAL INCREASE OF MILEAGE.
1830	23	....	1855	18 374	1 654
1831	95	72	1856	22 016	3 647
1832	229	134	1857	24 503	2 647
1833	380	151	1858	26 968	2 465
1834	633	253	1859	28 789	1 821
1835	1 098	465	1860	30 635	1 846
1836	1 273	175	1861	31 286	651
1837	1 497	224	1862	32 120	834
1838	1 913	416	1863	33 170	1 050
1839	2 302	389	1864	33 908	738
1840	2 818	516	1865	35 085	1 177
1841	3 535	717	1866	36 801	1 742
1842	4 026	491	1867	39 250	2 449
1843	4 185	159	1868	42 229	2 979
1844	4 377	192	1869	46 844	4 615
1845	4 633	256	1870	52 914	6 070
1846	4 930	297	1871	60 283	7 369
1847	5 598	668	1872	66 171	5 888
1848	5 996	398	1873	70 278	4 107
1849	7 365	1 369	1874	72 383	2 105
1850	9 021	1 656	1875	74 096	1 712
1851	10 982	1 961	1876	76 808	2 712
1852	12 908	1 926	1877	79 147	2 339
1853	15 360	2 452	1878	81 841	2 694
1854	16 720	1 360	1879	86 121	4 280

Of which about 4 700 miles are narrow guage.

That this does not compare unfavorably with what has been accomplished in other countries, appears from the following table of the population and railways of the world, at the close of 1875, which I also borrow from Poor's excellent manual for 1876–1877.

RAILROADS OF THE WORLD.

STATEMENT SHOWING THE AGGREGATE OF THE RAILROADS IN EACH COUNTRY AND THE RELATION THEREOF TO AREA AND POPULATION AT THE CLOSE OF THE YEAR 1875.

COUNTRIES AND STATES.	AREA.	POPULATION.		Railroads in Operation Miles.	RAILROAD MILES TO	
	English sq. m.	Census or Estim. 1875.	Ratio, sq. m.		Area sq m.	Inhabitants.
United States of America	3 026 504	43 785 718	14 4	74 658	40.5	586.5
Dominion of Canada	686 353	4 941 690	7.2	4 488	152.9	1 101.1
United States of Mexico	829 916	8 133 719	9.8	327	2538.0	24 873.8
TOTAL NORTH AMERICA	4 542 773	56 861 127	12.4	79 473	57.2	707.3
Central America and West Indies	151 001	2 593 739	17.2	611	247.1	4 245.1
South America	6 401 777	22 137 700	3.4	3 826	1673.2	5 786.1
TOTAL AMERICA	11 095 551	81 592 566	7 3	83 910	132.2	973 4
Europe	3 886 813	306 397 611	78.8	88 007	44.2	3 481.5
Asia	1 846 194	255 333 132	138.2	7 087	260.5	36 028.4
Africa	880 636	14 107 569	16 0	1 538	572.6	9 172.7
Australasia	2 406 070	2 235 079	0 9	2 148	1101.5	1 040.5
GRAND TOTAL	20 115 264	659 666 957	32.8	182 690	110.1	3 612.7
World without the Railroad	31 220 246	730 365 043	23.4	.....	.....	.....
WORLD IN GROSS	51 335 510	1 390 032 000	27.1	182 690	280.0	7 614.2

Since 1875, some 10 268 miles have been built in Europe, and about 5 000 miles in other parts of the world, outside of the United States, chiefly in Australia and India, so that the world's railways probably stand to-day as follows :

Europe.....	98 275 miles, or.....	47 per cent.	
United States.....	86 121 "	41 "	
Rest of the world..	25 000 "	12 "	
	209 396		

Thus our 50 millions of inhabitants have furnished themselves with 86 000 miles of railway, while the 306 millions of Europe have 98 000 miles, and the 1 050 millions of the rest of the world possess but 25 000 miles.

There was in Great Britain on the 1st of January, 1879, 17 333 miles of railway, on which there were about 32 000 miles of track, 12 969 locomotives, 418 322 passenger and freight cars, owned by the companies, in addition to some owned by private parties, and over which trains ran 222 376 114 miles, and conveyed 565 000 000 passengers.

The capital account of the English roads was 698 545 154 pounds sterling, or $3 380 958 545, thus giving an average cost of $195 059 per mile of road.

The average cost per mile in several other countries about the year 1875, was as follows :

France.....	1873	$152 500
Belgium.....	1873	111 342
Germany.....	1875	100 570
Austria-Hungary.....	1875	105 847
All Europe.....	1875	120 960
United States.....	1879	58 915

Thus our railroads have cost less than half as much per mile as those of Europe.

Going back one year, for purposes of comparison, on the 1st day of January, 1879, we had in the United States, 81 841 miles of railroad, on which there were 101 660 miles of track, or enough to encircle the globe three and a half times. There ran upon these roads 16 445 locomotives,

11 683 passenger cars, 4 413 baggage, mail and express cars, and 423 013 freight cars.

The capital invested was $4 772 297 349, or $58 915 per mile of railroad ; the gross earnings were $490 103 351, or $6 209.52 per mile ; the working expenses were 61.79 per cent. of earnings, or $302 528 184—say $3 887.10 per mile of railroad ; and the net earnings were $187 575 167—say $2 322.42 per mile, or 3.932 per cent. on the nominal capital.

While the greater cheapness of our American railroads is in some measure due to the comparative smoothness of much of our country, and to the absence of heavy land damages, much more is due to the methods of construction applied to the railroads themselves, to the cheap and efficient expedients which our engineers have introduced, and especially to the character of the rolling stock which we have adopted.

The early locomotives obtained an adhesion and tractile power equal to $\frac{1}{4}$ of the weight upon their driving wheels. I believe that in other countries $\frac{1}{7}$ of the weight is even now considered a standard and satisfactory performance, while our American locomotives, including the latest type, the "Consolidation" engine, of 50 tons weight, regularly work up to $\frac{1}{3}$ in winter, and $\frac{1}{4.5}$ in summer, of the weight upon their drivers, with occasional performances up to $\frac{1}{3}$, and even less.

That is to say, if a locomotive has 88 000 pounds weight upon eight driving wheels, and obtains an adhesion of $\frac{1}{7}$, it will pull a train equal in resistance to the lifting of a weight of 12 571 pounds ; while if it works up to $\frac{1}{4.5}$ in adhesion, it would pull 19 555 pounds, or 55 per cent. more under the same circumstances.

Not only do our locomotives pull greater trains than do European locomotives, in proportion to their own weight, but they run more miles in the course of the year : Stürmer's statistics for 1875, showing that the average train mileage for locomotives (not the engine mileage, but the mileage of passenger and freight trains, divided by the whole number of locomotives), was for all Europe, 15 720 miles per year, and for the United States, 21 900 miles per annum.

This has been accomplished by a series of improvements in construction, which have brought our locomotives materially to differ from their European prototypes, and which fairly entitle us to speak of them as American in design.

These improvements chiefly consist : First. In the substitution for a rigidly attached pair of leading wheels, of a four-wheeled truck pivoted

at its centre, or of a swing-beam pair of wheels, under the front end, thus allowing lateral play, and giving the engine great ease in passing curves ; and, also, Second. In the connecting together of the driving wheels and axles, with one or more pairs of equalizing levers, to distribute the weight among them, and thus keep its apportionment nearly constant, while the wheels are free to follow and adapt themselves to all the irregularities and deflections of the track.

These two features, together with careful counterbalancing and easy springs, have not only given our locomotives great ease and steadiness of motion, even over rough tracks, but have made them more efficient over good tracks. Moreover, outside cylinders and accessibility of parts, give great facility for repairs, and notwithstanding the higher prices which we pay in this country for labor and materials, our American locomotives are cheaper to build and to maintain than those of foreign makers.

This efficiency in the motive power has enabled us to cheapen greatly the construction of our roads, by locating them with sharper curves and steeper grades than would otherwise be possible, as is evidenced by the comparison of cost per mile already given.

There are, however, a number of features of European locomotive practice, which it would be well for us to study, and possibly to imitate, such as improved methods of boiler construction, economy of fuel, and better proportion of heating surfaces.

By calling attention to these, the editors of the *Railroad Gazette*, from whom many of the statistics hereafter to be given have been obtained, are doing the country, as well as engineers, a good service.

We have applied to railroad cars similar features of flexibility and diminished resistance, by placing under each end a pivoted truck of four wheels, instead of a single pair of wheels rigidly attached. This arrangement enables us not only to shorten the wheel base, but to lengthen the car. It passes with ease around curves even as short as 100 feet in radius, and improved design and workmanship, together with our tight journal boxes, lubricated with mineral oils, have reduced the resistance of cars so much, that recent experiments made upon several of our roads, indicate a rolling friction of only 4 or 5 pounds per ton, *on a level straight line at low speed*, or only one-half of the co-efficient as given in all engineering note books.

Until recently, the proportion of live or paying weight carried by our

freight cars, did not as well compare with their own dead weight, as in European freight cars. The latter, with four wheels, generally weigh 13 000 pounds, and carry 20 000 pounds when fully loaded. It took us a long while to realize that having started with 8 wheels under our cars, we could, by increasing their weight in some degree, at the same time increase their carrying capacity in still greater ratio, and so obtain better proportions. The more recent freight cars, however, those of the Pennsylvania Railroad, carry 40 000 pounds, and they weigh about 21 000 or 22 000 pounds, if built as box cars, and 19 000 pounds, if constructed as coal cars ; the latter especially, being exceedingly well designed.

And since I have mentioned the name of the Pennsylvania Railroad, allow me to call the attention of the members of this Society to the study and imitation of that splendid work, which, if not the most perfect, is certainly one of the most perfect railroads in the world. The expenditure of money, and thought, and care, which has been going on upon it for many years, has reduced the cost of transportation over it, to less than obtains on any other trunk line which crosses the Alleghany range.

There are two features of European practice, which, perhaps, it would be well for us to introduce in our freight cars. The first is the substitution of iron for the wooden sills, which now form their foundation. The second is the larger use of platform and gondola cars for carrying freight. Even dry goods and groceries, covered with tarpaulins, are carried on flat cars in England, where it rains much oftener than it does here ; and the ease and cheapness with which these cars are loaded and unloaded (with proper appliances) in comparison with our box cars, promises a notable economy of station labor.

We also continue to handle all goods at our depots with hand labor. At all stations where traffic is large, we might substitute machinery to advantage for many classes of freight. This offers a fine field of invention and adaptation for engineers or mechanics.

While paying much attention to cheapness in the transportation of freight, and obtaining results, as we shall see hereafter, which compare favorably with those obtained elsewhere, we have not been unmindful of the safety of passengers. Our safety platforms and power brakes, together with the extended use of the telegraph, have made traveling in this country generally as safe as it is abroad, notwithstanding the lighter character of our roads, and the fact that most of these are single tracked.

We have, however, much to do, particularly in introducing signals to control the movements of trains. This is done almost universally in Europe, and scarcely at all in this country. Not only is traffic comparatively light on many roads, but with us labor has been so expensive, that we have hesitated at adopting the block signals which require the attendance of numerous men. American inventors have turned their attention instead to automatic signals, of which there are several systems which promise well. It is to be hoped that they will be so improved, perfected and cheapened as to lead to their adoption.

Although our railroads were originally cheaply and imperfectly built, and although we pay in this country a great deal more for labor and material than the prices which obtain in Europe, we have nevertheless reduced the cost of transportation to as low figures, if not lower, than any which obtain on the other side of the ocean. The grindstone of competition between the railroads themselves, and with canal, river, and lake routes, has reduced freight transportation to such a fine point, that our railroad managers have devised new and cheaper methods of doing their work, have learned to operate their roads with a smaller proportion of men, and have accomplished results which astonished even themselves.

It is difficult to make comparisons of rates and costs between different railways, because scarcely any two of them are placed under precisely the same circumstances, but it is known that the lowest rates in England are given on mineral traffic. This is understood to be about $\frac{3}{4}$ of a cent a ton a mile, while the regular rate from Chicago to New York, upon domestic produce (grain, flour, provisions, lard, etc.,) is now $\frac{8}{8}$ of a cent a ton a mile, and in times of sharp competition has been $\frac{7}{10}$ of a cent a ton a mile.

The English railroads do not report their earnings and expenses per ton per mile, but the German Union railroads (which include about 27 000 miles in Germany, Austria, and Hungary, as well as some in Belgium and Holland,) do, as well as the Belgian state railroads. In the table which follows, the freight revenue, expenses, and profits of these are given for such years as were accessible, and for purposes of comparison, similar figures are given for the railroads in such American States as report the necessary data, as well as for a number of individual American railroads, of which the revenue and expense, per ton mile, have been published in the *Railroad Gazette.*

RAILWAYS.	YEAR.	REVENUE. CTS. PER TON MILE.	EXPENSE CTS. PER TON MILE.	PROFIT. CTS. PER TON MILE.
German Union R. R.	1875	2.100	1.194	0.906
" "	1876	2.070	1.154	0.916
" "	1877	2.050	1.094	0.956
Belgian State R. R.	1877	1.431	0.856	0.575
State of Ohio	1876	1.117	0.801	0.316
" Michigan	1878	1.053	0.632	0.421
" Illinois	1879	1.028	0.617	0.411
" Massachusetts	1879	1.838	1.066	0.772
" New York	1877	1.059	0.781	0.278
" "	1878	0.999	0.690	0.309
N. Y. Central	1879	0.796	0.541	0.255
Erie	"	0.780	0.561	0.219
Pennsylvania	"	0.824	0.480	0.344
Boston & Albany	"	1.073	0.622	0.451
Pitts., Cin & St. L.	"	0.720	0.420	0.300
Col., Chi. & Ind. Cent.	"	0.700	0.590	0.110
Vandalia Line	"	0.931	0.715	0.216
Mich. Central	"	0.692	0.407	0.285
Lake Shore	"	0.642	0.398	0.244
Clev., Col., Cin. & Ind.	"	0.697	0.575	0.122
Chicago & Alton	"	1.054	0.558	0.496
Illinois Central	"	1.520	0.640	0.880
Chi. Mil. & St. P.	"	1.720	0.941	0.779

Thus, it will be noted, that the profit alone on freight is more on the German Union Railroads than the gross receipts of the three American trunk lines, and although it is true that the passenger rates are materially lower in Germany than they are in the United States, yet if the traffic of the New York roads had been carried at the German rates for 1877, the profit alone would have been $52 500 000 more than it was; if carried at the Belgian rates, both for passenger and freight, the profit of the New York roads for 1878 would have been more by $13 000 000; that is to say, twelve millions less upon passenger, because of the lower Belgian rate, and twenty-five millions more on freight than it was, and

these sums may fairly be said to have been saved to the public by the economical operations of our roads.

In fact, sharp competition and the incessant demands of the public, have for the past few years diminished rates so rapidly, that, as a whole, our railroads are now paying smaller returns upon the entire capital invested in them than those of most of foreign countries, and the people of the United States have since 1873 had their property transported for less than it was reasonably worth. It has been shown in giving the net earnings of all our railroads, that for the year ending January 1, 1879, they earned 3.93 per cent. upon the total capital invested in them, while the railroads of Europe in 1875 earned the following returns upon their capital :

Great Britain	4.4 per cent.
France	5.1 "
Germany	5.1 "
Austria-Hungary	3.9 "
Russia	4. "
All Europe	4.3 "

It may be claimed that the capital of our American roads exceeds their real cost, in consequence of what has been called the watering of the stock of some of them ; but it is believed that much larger sums than those so added to the stocks of the successful roads, have been wiped out and lost in the reorganization of the unsuccessful roads, so that this return of 3.93 per cent. upon the entire capital of all our roads seems an insufficient return in a country where money brings six to twelve per cent. interest. If, therefore, railroads are to continue to grow (and as only about one-half our territory is as yet provided with them, we shall doubtless have many more miles to build as population increases), it may be necessary that the reduction of rates shall be arrested for a while at least. They have been reduced not less than 56 per cent. in the State of New York, and about 45 per cent. in the State of Massachusetts, between 1868 and 1877, while in the German Empire during the same period they were only reduced 22½ per cent.

As Americans, we have no reason to be dissatisfied with the results accomplished thus far. We have succeeded in so organizing labor, that while we pay it from 30 to 50 per cent. more than in Europe, we build our railways for about one half the cost, and we transport freight over

them, with the aid of our machinery, at materially cheaper rates than those which obtain in other parts of the world.

Not only should engineers endeavor still further to improve and to cheapen the construction, and especially the operation, of our railroads, but they should now find in foreign countries, as yet unprovided with them, fields in which they can introduce the features of economy which we have developed.

At home we shall doubtless continue to build new lines in the same cheap, light style which we have made so efficient, and we shall largely extend the narrow gauge in sparsely settled districts. We should, however, so locate our roads as to secure the best possible line and gradients, even if after they are adopted, we do not bring the embankments to the full heights, in order to save present expense. As population and traffic increase, we can, if the works are well planned for that purpose, rebuild, add to and improve them, so as to diminish the cost of transportation, to the best economy.

Street Railways.

While we have been extending steam railways through almost all parts of our country, we have also endeavored to avail ourselves of diminished traction, by laying tracks down in our cities to be operated by horses. It is estimated that there are now about 3 500 miles of horse railways in the United States, and considerable additions are in progress.

Transportation by horses is slow, however, and the want has been felt in several of our cities of some method of using steam power as a motor, to increase the speed and diminish the cost. This has been accomplished in London by the building of underground railways, which, however, as they cost about a million and a half of dollars a mile, can only be introduced where the traffic is very large. In New York the problem has been solved by building elevated railroads which run upon girders supported above the streets by iron posts, and which cost about $300 000 per mile.

In order to avail of this method of rapid transit in other American cities, a decided reduction in the cost of the structure will perhaps be necessary, and several engineers are now devising and endeavoring to introduce cheap structures for that purpose.

Bridges.

While it is true that bridges were built centuries before engineering was recognized as a distinct profession, it is true equally that engineers, admittedly to-day, are the bridge builders of the world. Our predecessors of earlier days worked in wood and stone, and their rules of construction were founded upon the cut and try method. We have now added iron and steel as constructive materials, and it becomes a part of our duty to determine upon scientific principles the proper distribution of strains, and the due proportioning of materials to resist them, so as to secure the greatest amount of efficiency at the least cost.

As a temporary expedient, wooden bridges were early built in this country, under the familiar names of the Burr truss and the Town lattice, but after the introduction of railroads, it became necessary to provide a more efficient system of counter bracing, than could be attained in the earlier forms of trussing. The Howe truss was invented, and was found to be the simplest and best arrangement that could be adopted. This bridge is undoubtedly the best of its kind in the world, and has been of immense service in facilitating the development of our railway system, through what may be called its pioneer stage. From data obtained in the railroad reports of the States of Pennsylvania and Ohio, it is estimated that there are now in the United States about 900 miles of bridges upon our railroads, of which, perhaps, one-third are permanent structures, of stone and iron, and two-thirds at least are temporary structures of wood, which will have to be rebuilt by our engineers.

The demand for more permanent structures has brought about the substitution of iron for wood. As might have been expected, the forms of trussing with which we were most familiar in wood, were the first upon which experiments were made in iron; while, however, our English brethren 30 years ago were building plate girders and tubes, our venerable Honorary member, Squire Whipple, was studying the subject, and with characteristic modesty, laying down the principles of a science of bridge construction based upon determining the action of the forces, in skeleton structures, by rigid mathematical calculation. His book, printed by his own hand in 1847, contains nearly all that is vitally important connected with the theory of fixed spans, and his bridges stand to-day as monuments to his skill, and reminders to us of the debt we owe to that distinguished engineer.

The concentration of the material into a few parts resulted in the use of the pin connection at the joints, in contradistinction to the rivet, as used in other countries. For compression members, cast iron very readily adapted itself to top chords and posts, and until late years, was considered satisfactory.

To resist tension, it became necessary to forge bars with enlarged heads, now known as eye-bars, and to determine the proper proportion of pin and eye, to the section of the bar, so as to develop its full strength. In this we have been reasonably successful, and with the introduction of improved machinery, we have been enabled to make and secure uniformly reliable bars at a very low cost. To this fact, perhaps, more than any other may we attribute the success which has attended the labors of American bridge builders.

The eye bar is the distinctive feature of the pin connected bridge, and upon it depends in a large measure its economy.

A bridge which can be taken upon the staging in pieces and made self-sustaining, between daylight and dark, would seem to need little more to be said in its favor, as compared with the tedious and expensive methods, rendered necessary in the erection of riveted structures.

It must not be assumed, however, that American bridges are all pin connected. Many of the best railroads in the country prefer riveted bridges on account of their superior rigidity, particularly in short spans, and from the fact that they are not easily knocked down by derailed cars, a point which has not received that attention which it deserves. Our shop practice in riveted work is generally good, and we have effected some improvements on the European methods, in general design ; but we are yet deficient in experimental knowledge as to the value of the rivet connections, particularly when applied on one side of an angle bar, and we have not yet been able to avoid cross strains upon the chords, at the intersection of the diagonals.

The English practice of drilling all holes on the ground where splices occur, has not been found necessary here, when a proper system of automatic spacing is employed.

The chief defects in our bridges have arisen from the weakness of the floor, and when it is remembered that locomotives have increased in weight within the past few years about forty per cent., and that the floor is subjected to its maximum strain every time that a locomotive passes over the bridge, it will be apparent that a decided increase in strength must

be given to this portion of the structure, and in all probability it will be necessary to renew many of our earlier bridges in this particular.

Again, there should be more efficient provision against disaster from the derailment of cars. The less wood we have on iron bridges the better; ties are, of course, a necessity, but they should be supported on at least four iron stringers, and be spaced 8 to 10 inches apart, and secured against spreading. Joint boxes should be avoided. End posts should be continuous to the masonry supports, and secured to the top chords, and to each other by efficient portals. Horizontal bracings, to resist vibrations and wind pressure, should be made more effective than they are, particularly at the chord connections. There are many other minor details, it is safe to assume, which will be perfected in due time, but upon the broad question of experimental information, we must look for aid to every member of the profession.

A testing machine of the very best description, belonging to the United States Government, is now in working order, at the service of all such as may desire to avail themselves of it. I believe the time has arrived when a committee of this Society should be appointed for the purpose of inviting the co-operation of manufacturers, in the effort to obtain more accurate knowledge of the metals and manufactured shapes which enter into our important structures.

Particularly is this the case in regard to the material which we call steel. Of late, the manufacture of steel by the pneumatic and open hearth processes, has been undergoing a prodigious development, and we may now assume that a metal can be obtained by either of these methods, more uniform in its character than the best iron yet offered in merchantable quantities; possessing an elastic limit of 40 000 pounds per square inch, and an ultimate strength of 65 to 70 thousand pounds per square inch, and capable of being manufactured into any of the required shapes for structural purposes, at a cost which, taken in connection with the saving involved in dead weight, must ensure its substitution for iron in the larger spans at least ; and it is confidently asserted by those whose experience entitles them to speak with authority, that the day is not far distant when steel will be produced at a less cost than iron is at present by the hand puddling process.

All the more important, therefore, is it that we should inform ourselves by the most thorough tests of the characteristics of steel, if we would maintain the high standard of American bridge construction.

We have thus far applied this metal to but few structures. It has been used in the bridge at St. Louis, in the bridge at Glasgow, and is now being used in the East River Bridge, designed by Mr. Roebling, of 1 600 feet span, and in parts of the Plattsmouth Bridge, which you are invited to visit. It is hoped that the engineers of these pioneer structures will communicate to the Society the information which their experiments have elicited concerning this material of the future.

The day cannot now be far distant when the merits and economy of the American type of bridges will be recognized by other nations. Already, notwithstanding the fact that labor and materials are cheaper in other countries than in this, we are enabled to compete successfully in Canada and in South America. I believe that a well directed effort to make known abroad, what we have accomplished in this branch of engineering during the last fifteen years, would open a market for our bridges and bridge designs in Europe and in Asia.

Preservation of Timber.

The rapid disappearance of the forests in this country, and the consequent growing scarcity of timber, point to the necessity of sooner or later adopting some method of wood preservation.

Several processes have been in use in Europe for many years, with satisfactory results, but in this country success has not been the rule. Whether these failures have been due generally to imperfect preparation, or because we have blindly followed the foreign methods, without modifying them to meet the different conditions here, we are not prepared to say; but the whole question is so important that a report of our failures even more than that of our successes would be of great value to engineers.

It is hoped that all of those members of this Society who have had any experience whatever in this line will communicate the results to the standing committee, which has been appointed during the past year to investigate the subject of wood preservation.

River Improvements.

We have as yet done little toward regulating and improving our rivers. Blessed with a magnificent system of internal navigation, which, as Mr. Fink and Mr. Blanchard have recently shown, virtually

compete with and regulate freight upon almost all of our railroads, we have directed our attention rather to the craft that navigate them than to the streams themselves.

The further demand for cheaper transportation, however, as well as the higher spring floods and the lower summer waters, which come with the destruction of the forests, make it necessary that we should within a few years begin extensive river works. Colonel Mason, late member of this Society, showed us in building the St. Joseph Bridge that even the Missouri River was easily controlled, and made to flow wherever the engineer desired, by throwing out cheap and apparently frail brush dykes. A much greater and more original work has since been accomplished by the same simple means by our distinguished member, Captain James B. Eads, who, taking in hand the smallest and most unpromising pass of the Mississippi River, with seven feet of water over its bar, has in four years transformed it into the best access from the river to the sea, with thirty feet of water over the bar, at the cost to the nation of only $5 250 000, while the ship canal which had been proposed by other parties was estimated to cost $10 000 000.

The same far-seeing engineer is now engaged in studying the remainder of the course of the Mississippi River, and devising plans for its control and improvement. You have probably read the report to Congress of the board on which he has been acting, in which, differing widely from their predecessors, they propose to regulate the depth and flow of the river, by reducing its width at those points where it spreads into shallow sand bars.

The reasons by which these proposals are supported seem so sound, that it is to be hoped our Government will soon take steps to test the efficacy of the proposed methods upon an adequate scale.

The first of what is likely to prove a series of works to control the low water discharge of our rivers is being built upon the Ohio River at Davis' Island dam, five miles below Pittsburgh. It is a movable dam, of which you will find a brief descriptions in *Scribner's Monthly Magazine* for this month (May, 1880).

The French have preceded us in works for regulating the flow of their navigable rivers, and have designed a number of types of moveable dams (which they call "barrages"), which are well worthy of study and possibly of imitation. We shall doubtless make some changes, and perhaps improvements in them, to adapt them to our necessities, and to

our constructive methods; and this class of works should hereafter attract the study and attention of the members of our profession, more than has been the case hitherto.

The boldest and most interesting harbor work now being carried on by our Government is probably the removal of the rocky obstructions in the East River of New York, at Hell Gate.

General Newton, as you know, sank a shaft in the rock at Hallett's Point to a depth of some 50 feet below low water, honeycombed the rock with 7 426 lineal feet of galleries in various directions, and charging 4 427 drill holes in the remaining pillars and roof with 49 915 pounds of "rend rock," "vulcan powder" and "dynamite," blew up the whole Point, extending over three acres, and containing 63 135 cubic yards of rock, on the 24th of September, 1876. So accurately were the explosives located and proportioned, by the mathematical formulæ worked out for the occasion, that not the slightest damage was done to the surrounding houses and premises. The debris has since been removed with a grapple to a depth of 26 feet below low water.

General Newton is now engaged in undermining in a similar manner the rocky island of eight acres (mostly under water) known as "Flood Rock," in the same vicinity. He has sunk a shaft, and driven, to May 1, 1880, 5 273 lineal feet of galleries, from which he has removed 19 044 cubic yards of rock, leaving a roof varying from 8 to 19 feet in thickness between the top of the galleries and the water in the tide way, which is from 6 to 12 feet deep.

The holes are all bored by machine drills driven by compressed air.

Light-houses.

From the report of the Light-house Board for the year ending June 30, 1879, it appears that the Government has erected the following light-houses:

First order	47
Second "	26
Third "	55
Third and a-half order	10
Fourth "	200
Fifth "	123
Sixth "	165
Total	626

River lights—Mississippi, Ohio and Missouri Rivers	737*
Buoys in position	3 114
Fog signals—steam or air	56
Light ships	31

As a measure of comparison, it may be interesting to note that on the 31st of December, 1878, England reported 597 light-houses and France 346 light-houses.

Many of the 626 reported by the Light-house Board are doubtless temporary structures, and they will have to be renewed; but in the meantime they are rendering good service to navigation, by lighting our coasts and harbors.

Marine Engineering.

Our vessels engaged in foreign trade which had gradually increased to an aggregate tonnage in 1861 of 2 642 628 tons, have dwindled away ever since, until in 1879 they comprised but 1 491 533 tons. These consisted of only 168 steam vessels, measuring 156 323 tons, and 2 549 sailing vessels, measuring 1 335 210 tons.

The tonnage movements of our ports showed that in 1879 the entrance of American vessels engaged in foreign trade aggregated 3 049 743 tons, so that they averaged a little over two trips per year, while the tonnage of foreign ships entered was 10 718 394 tons, or 3½ times our own.

Originally caused by our civil war, the continuance of this decay of our marine engaged in foreign trade, is attributed to a concurrence of two principal causes: First, the substitution of steam for sailing vessels in the commerce of the world, consequent upon the improvement in ships and compound engines made by the English, and secondly, the demonstration that iron vessels are more economical in operation than wooden ones.

Mr. Joseph Nimmo, Jr., Chief of Bureau of Statistics, says, in his report for 1879, "The tonnage of iron vessels built in this country during the last five years amounted to only 97 872 tons, whereas the iron

* These lights mainly consist of lanterns suspended from wooden scaffolding easily moved; their position is shifted to correspond to the shifting of the channel. They have given such great satisfaction to those interested in river navigation that they are now regarded as indispensably necessary.

ship building of Great Britain during the last five years reported, amounted to 1 927 710 tons. * * *

"Probably no other branch of American industry comes so directly into competition with foreign industries, as do those of building vessels, and operating them in international commerce. * * *

"So long as wooden sailing vessels were the only vehicles of commerce upon the ocean, American tonnage rapidly increased. * *

"The United States had, about the year 1850, attained nearly to the first rank among the maritime nations of the globe. * * *

"The change from wooden to iron vessels began to take place about the year 1857. * * *

"The difference between the cost of building iron vessels in this country and in Great Britain is much less at the present time than it was ten years ago. This is chiefly due to the reduction in the wages of labor and in the price of materials in the United States." * * *

Thus, in our foreign marine alone, of all our industries have we lost ground. Although Fulton, an American, was the first to apply steam to navigation; although an American steamer, the Savannah, in 1819, was the first to cross the ocean, we have not only failed to keep our position in foreign shipping, but we have lost numerically, and our tonnage has actually dwindled away.

The diminished difference above noted between the cost of building iron ships in this country and in Great Britain is believed not to be wholly due to reductions in wages, and in the price of materials; much of it is attributed to improved organization in our ship yards, and to labor-saving appliances. It is believed, that more remains to be done in the same direction.

Here, then, is a splendid field for our marine engineers and ship builders. Let them accomplish for the iron or steel steamer what has been done for the railway, the locomotive, and the iron bridge; and so improve the design, the proportions, the framing and machinery of the ships, as well as the organization of the labor engaged in their construction, as to do their work, by the aid of machine-tools, and a judicious system of piece work, so cheaply as to enable us to overcome the difference in the cost of labor, and take again our proper rank upon the ocean.

The marine engaged in our internal navigation, and coasting trade,

has, however, nearly maintained its position, notwithstanding the extension and competition of the railroads.

Arriving at a maximum of 2 897 185 tons in 1861, it still aggregates for 1879 2 678 067 tons, of which 1 019 848 tons are propelled by steam. It consists of 13 085 sailing vessels, measuring 804 688 tons, engaged upon the Atlantic and Gulf coasts, and on the Pacific coast; and of 1 408 sailing vessels, measuring 282 916 tons, upon the northern lakes.

There are also upon the northern lakes 868 steam vessels, measuring 194 416 tons, together with 170 barges aggregating 42 226 tons, and 548 canal-boats* aggregating 44 774 tons.

On our rivers which empty into the Atlantic and Gulf coasts there are 2 067 steam vessels, measuring 499 002 tons; 764 barges, with 159 041 tons, and 658 canal-boats*, with 58 963 tons.

On the rivers which empty into the Pacific we have 267 steam vessels, measuring 77 050 tons, and 87 barges with 14 596 tons.

While on our western rivers there are 1 199 steam vessels aggregating 249 380 tons, and 1 373 barges, with 251 015 tons.

Thus it will be seen that of our domestic tonnage, 4 401 vessels out of 22 504, and 1 019 848 tons out of 2 678 067 tons are propelled by steam, and this proportion of steam vessels engaged in our domestic trade, as well as the comparatively short distances over which they ply, enables them to move many times the aggregate tonnage of our foreign trade.

This domestic steam marine presents nearly every variety of practice, from the coasting steamer and the lake propeller, to the western steamboat, some of them of such light draft that it used to be said that they could run on a heavy dew. Our daily experience proves how well adapted the vessels are to our requirements, and the civil war showed that they could be made effective in supplementing a weak war navy.

One engineer, still living, has contributed more than any other to this great advance. I refer to Captain John Ericsson, he, who competed with Stephenson in 1829, and built the locomotive "Novelty," which only failed, by the breaking of a part of her machinery, from carrying off the first prize ; who, in 1837, designed and placed on the Delaware and Raritan Canal, the first screw propeller ever in actual service ; who

* As under existing laws very few canal-boats are enrolled and licensed, only those which come out of canals, and navigate naturally navigable waters, are included in the above list which is taken from the reports of the Bureau of Statistics.

designed and built, in 1844, the frigate Princeton, the first steam war ship of the United States, and has since given us the hot air engine, a surface condenser, a vibrating piston and crank applied to marine engines, a deep sea sounding lead, a gun carriage and a compressor to resist the recoil; who sent down to Hampton Roads, in 1862, the "Monitor" to turn the fortunes of the war, and who, still keeping up, in his old age, his incessant labors, is now engaged in investigating and inventing a new motor, the power of which he proposes to derive from the sun, while he is designing and building his new ship, "The Destroyer," which he expects to sink all war ships she may attack, to the bottom of the ocean.

Telegraphic Engineering.

The lines of telegraph are being extended so rapidly that it is difficult, even for their owners, to state the aggregate quantities at any particular time.

The best information, however, which can be obtained is that on the 1st of January of this year, there were 119 042 miles of telegraph lines in the United States, and 299 859 miles of wire, without counting those lines specially used by the Gold and Stock Telegraph, and the District, the Fire Alarm and Burglar Alarm Telegraphs in the various cities.

One telegraph company alone, the "Western Union," had in June, 1879, 8 534 offices, from which were sent and received 25 070 106 messages during the preceding year.

Equally prompt has been the application of the telephone, which looked upon doubtfully, or only as a toy, when it was first shown by Professor Bell at our Centennial Exhibition four years ago, has so rapidly become a necessity, that there are now in this country 121 000 instruments at work, connecting our business places and dwellings with each other, and with the central offices, by means of which we are almost instantly brought within speaking distance of the persons, miles away, with whom we have to transact our business.

You are so familiar, however, with the telegraph and telephone, that it may be more interesting to you to call your attention to some of the house uses of electricity, which are becoming part of our common life. Within the last few years we have been introducing electricity into our houses, and virtually made of it a new domestic servant, by what are called the burglar and fire alarm systems; not only does it ring bells, and summon

the other servants, (and in recent appliances, keep these bells ringing until the summons are answered), but as a burglar alarm, it is on the watch at night, and in a house properly fitted with these contrivances, the whole or any part can be attached or detached at pleasure. The windows may be left partly open at top or bottom for ventilation, if desired ; and once the current turned on, any attempt to alter their position, or to effect an entrance from the outside, causes an alarm which can be stopped only by the person in charge. A glance at the annunciator determines the position of the burglar, or by pressing a knob at the instrument, it shows what doors or windows are open. To accommodate late comers, the front door can be disconnected, or with a special key it may be opened without causing an alarm. In the absence of the family the bell may be made to ring outside, or in a neighbor's house, or at the Police Headquarters; while the clock that calls the servants in the morning, at any hour desired, disconnects such parts of the house they are allowed to use, so as not to disturb the rest of the family.

Applied to safes in counting-houses, or to stores containing valuable goods, the burglar alarm rings the bell at Police Headquarters, and at the same time indicates the point of attack. In a recent case in New York, the burglars, who had broken into a silk house, so promptly set off the alarm, that they were surrounded by the police and captured, as they were taking the goods down from the shelves. The system is being rapidly introduced in stores, counting and banking houses, and in connection with time locks on the safes, affords such good protection as to make watchmen almost superfluous.

Applied to fire alarm, electricity renders still more important domestic service; not only does it advise all the fire engines located in a particular district, whenever an alarm is sounded from a street corner, but it sets machinery at work which unhitches the horses from their stalls, wakes up the firemen (and tumbles them out of bed in some cities), harnesses the horses, lights the fires, and opens the doors of the engine house, so that the machine is ready to start in eleven or twelve seconds after the alarm is sounded; but the fire alarm is also extended to private houses, and there presents itself in the shape of three unobstrusive knobs. Push the first and you summon the fire department; touch the second and a police officer makes his appearance; press the third and a messenger comes to run your errands. Moreover, by means of the Pyrostadt, should a fire break out during your absence, the expansion of a

metallic bar makes an electrical connection, which sets off the alarm and summons the fire engine. It is believed that these and other uses of electricity are about to be largely extended in our country, and several members of our Society have lately turned their attention to them.

Gas Engineering.

Another department of engineering represented in this Society has for its object the construction and management of works devoted to the manufacture of illuminating gas.

In 1850 there were only about fifty gas light companies in the United States. In the thirty years which have elapsed since that time, the number of companies has increased to nearly nine hundred, with a capital aggregating more than two hundred millions of dollars. The amount of gas annually manufactured for illuminating purposes is probably not less than twenty thousand millions of cubic feet. The magnitude of the business may, perhaps, be better comprehended from the statement that this entails the mining, transportation, handling, and carbonizing of something over two millions of tons of coal per annum.

The gas makers, however, unlike railroad managers, have not until recently been compelled, by sharp competition, to study close economy, but the pressing demand for a reduction in the price of illuminating gas to the consumer is, to-day, necessitating the application of scientific education in all the departments of its manufacture.

The improvements that have been made thus far have consisted mainly in the setting of the retorts, and in more efficient condensation and purification. The competition brought about by the introduction of other illuminating agents is compelling the attention of engineers to the application of machinery, in the various operations involved in gas making, for the purpose of reducing the cost of labor and also developing the useful application of the various residual products, which result from its manufacture.

In other countries than the United States, particularly in England and France, the value of these residual products, together with the lower price of labor and material has enabled the companies to reduce the price of their gas much below the point at which it can be profitably sold

in this country. In the city of London the sale of residual products returns to the companies sixty-six per cent. of the cost of their coal. When the demand for these products increases to that extent in this country, a very decided reduction of the price of gas to the consumer can be made without reducing materially the profits of the companies.

The most recent application of the results of scientific investigation consists in the introduction of gas furnaces, and of mechanical means for charging and discharging the retort.

In gas furnaces very decided success has been reached not only by foreign engineers but by engineers in this country. The efforts that have been made in mechanical stoking, have heretofore resulted only in partial success, but within the last year a machine has been invented and put into practical operation in the city of Cincinnati, which bids fair to accomplish the desired result.

Much attention has been paid of late to what is called water gas, which consists, in principle, of the decomposition of steam by means of incandescent fuel, the resulting products of which are carburetted with petroleum to give it illuminating qualities. Claims of superior cheapness have been made by the promoters of this process, while coal gas makers claim that gas can be made from coal as cheaply as by any of the water gas processes. As the latter have been largely introduced in some places, time will undoubtedly show which party is entitled to the greatest amount of credence, but as yet by far the largest proportion of illuminating gas sold in this country is made from coal.

Metallurgy and Mining.

The growth of metallurgical and mining industry in the United States has been indeed gratifying. I fear that bare statistics will fail to convey an adequate idea of what has been accomplished, but I will give them to you notwithstanding.

And first as to that most useful of all metals, iron : The reports of the Iron and Steel Association show that, beginning in 1721 with six furnaces and nineteen forges, we now have 228 anthracite blast furnaces, 203 furnaces which use bituminous coal and 266 charcoal furnaces, or 697 completed furnaces in all, which are stated to have, if all were in blast together, a capacity of making 6 500 000 tons of pig iron a year.

We are now the second iron producing nation in the world, England being the first and Germany the third, while 44 new furnaces are reported as being built. We have in addition 382 rolling mills and steel works, containing an equivalent of 4 467 single puddling furnaces, 2 419 heating furnaces, and 1 397 trains of rolls, with a capacity of four millions of tons a year in finished iron. Seventy-three of the rolling mills have nail factories attached, with 4 152 nail machines, and to make the list complete, we may add that there are in addition 69 forges, with a capacity of 85 000 tons a year, and 59 bloomaries, with a capacity of 80 000 tons a year.

From an advance copy of the Report of the Iron and Steel Association for the current year, kindly furnished by the Secretary, Mr. James M. Swank, I am enabled to give you the summary of the production of iron and steel in the United States during the past eight years : (see opposite page).

Mr. Swank says in his report : " Our steel industry is now the second in the world in productive capacity, and in a year it will pass that of Great Britain, and take the first rank. The increase within the past year in the capacity of our Bessemer and open hearth works, either completed or projected, is equal to an addition of 50 per cent. to the capacity which existed in 1878."

We now have eleven Bessemer works in the United States and two works are building. These contain twenty-two completed converters, and ten are building. We have a present capacity of 1 250 000 tons, and will have a capacity when the additions are completed of 1 750 000 tons a year, or enough to lay or to relay about 18 000 miles of railroad per annum.

The 22 completed converters have an aggregate capacity of 141½ tons, so that to produce the estimated output of 1 250 000 tons they must average 13.38 blows a day for 300 days in the year. While at work the converters average over 25 blows a day, while as many as 58 have been obtained from one vessel in 24 hours. Results which are thought to be much in advance of the average foreign practice, and which are chiefly owing to the labors and the skill of Mr. A. L. Holley, member of this Society, and the Consulting Engineer to all the Bessemer works in this country.

General Summary of the Production of Iron and Steel during the past Eight Years.

The appended table shows in tons of 2 000 pounds the production of all kinds of iron and steel in the United States from 1872 to 1879. In nearly all the branches of the domestic iron and steel industries which are here enumerated there has been an increased production in 1879 over 1878, and in most of them a very considerable increase.

Products.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.
Pig iron	2 854 558	2 868 278	2 689 413	2 266 581	2 093 236	2 314 585	2 577 361	3 070 875
All rolled iron, including nails and iron rails	1 847 922	1 857 450	1 694 616	1 599 516	1 509 269	1 476 759	1 555 576	2 047 484
All rolled iron, including nails and excluding rails	941 992	1 076 368	1 110 147	1 097 867	1 042 101	1 144 219	1 232 686	1 627 324
Bessemer steel rails	94 670	129 015	144 944	299 863	412 461	432 160	550 398	683 964
Open-hearth steel rails	.....	.....	.....	.....	.....	.....	9 397	9 149
Iron and all other rails	905 930	761 062	584 469	501 649	467 108	332 540	322 890	420 160
Rails of all kinds	1 000 000	890 077	729 413	792 512	879 629	764 709	882 685	1 113 273
Kegs of cut nails and spikes, included in all rolled iron	4 065 322	4 024 701	4 912 180	4 726 881	4 157 814	4 828 918	4 396 130	5 011 021
Crucible cast steel	29 260	34 786	36 328	39 491	39 382	40 439	42 906	56 780
Open-hearth steel	3 000	3 500	7 000	9 650	21 499	25 631	35 125	50 290
All other steel, except Bessemer	7 740	13 714	6 353	12 607	10 396	11 924	8 576	5 464
Bessemer steel ingots	120 108	170 652	191 933	375 517	525 996	560 587	732 226	928 972
Blooms from ore and pig iron	58 000	62 564	61 670	49 24[illegible]	44 628	47 390	50 045	62 353
Spiegeleisen, included in pig iron	.....	.....	.....	7 832	6 616	8 845	10 674	13 931

In addition to these there are 22 open-hearth steel works, with 33 furnaces, and three are building, with six furnaces, with a total capacity 275 000 tons in ingots. We have, moreover, 35 crucible steel works, and three are building, which will increase our capacity to 90 000 tons a year, besides some miscellaneous steel works, reported as 40 in number.

I will not weary you further with figures, and show our production in anthracite coal, in bituminous coal, in lead, zinc, copper, gold, and silver; although we have, since 1849 (thirty years), produced $1 493 843 430 in gold, and since 1858 (twenty-one years) produced four hundred and twenty millions in silver, but I may be permitted to refer to a few engineering features which mark our more recent American practice.

Among these is the hydraulic system of mining earthy deposits which contain gold dust, even when so little as one cent to the cubic foot. The water is brought sometimes many miles in open ditches, and delivered at the bottom of the mountain to be washed away, through pipes terminating in a flexible hose. Under the impingement of the stream which issues from the nozzle with a head of 200 to 500 feet, the earth melts away like snow, and the economy of labor produced will be best appreciated by an application of this process which took place last April, on the Central Pacific Railroad, near Alta, where a slide brought down upon the track a mass of earth so great that it was estimated that it would take several weeks to remove it with the pick and shovel. The hydraulic engineers being called upon for help, brought up their pipes and monitors, constructed a flume from a ditch which was fortunately near at hand, and in fourteen hours piped away the whole mass of debris which had been the despair of the railway men.

In the reduction of the silver ores such improvements have been made in machinery as very greatly to reduce the cost of working them. The stamp mill, for instance, an old German invention, has been so modified as to increase tenfold its effectiveness, and make it almost an American invention. Such progress has been made in the smelting as to render us independent of foreign works, and few, if any, of our ores are now sent abroad for reduction.

We have also introduced original methods in the extraction of those ores, and on the Comstock lode, which has produced nearly 200 millions of dollars of the 420 millions of silver thus far obtained in the United

States, shafts have been sunk about 3 000 feet deep, which are among the deepest in the world, in a rock which heats the air and water in the mines from 120 to 132 degrees Fahrenheit, thus making these by many degrees the hottest mines known. These have been worked by a novel system of ventilation, by which dry hot air is supplied to the miners, while they have unlimited access to ice water.

Great progress has also been made in applying quick explosives both to tunnelling and mining works, and the Sutro Tunnel, just completed to a length of 20 170 feet, bears evidence to the energy and enterprise of our miners, who have also succeeded in accomplishing great economical results with some of the largest blasts which have been fired in any country.

The discovery of petroleum, of which we produced 19 741 661 barrels, valued on the spot at $17 076 836, from 11 960 wells last year, has caused a revolution in the art of sinking artesian wells for oil, 3 038 of which were put down in 1879.

Such improvements have been made in the tools, and derricks for working them, that the well-borers now generally sink a hole five inches in diameter one thousand feet deep in twenty-five days, an average of forty feet a day, and at a cost not to exceed, including machinery and derrick, of $4 500, while the old pole tools, which these appliances have replaced, could make a progress of but 4 or 5 feet a day. Some of these wells have tapped reservoirs of natural gas instead of petroleum, and this has been quickly utilized in steam engines or in furnaces, while one town at least, that of Fredonia, in the State of New York, is lighted by natural gas at a very small cost.

Reference may also be made to the purely American invention of what is called driven wells, in which, instead of digging in the ordinary manner, an iron pipe, perforated at the bottom and shod with a steel spindle, is simply driven in the ground, in a few hours, to the water-bearing stratum, and yields, upon the application of a pump, nearly as much water as an ordinary house well.

There are yet great possibilities for our mining engineers in the scientific improvement of the present methods, in devising of new machines to work in the mines, of cheaper methods of mining the ores, of reducing them with a smaller consumption of fuel, and of a more complete extraction of the useful metals and minerals from them.

All other industries are to agriculture as dust in the balance ; for if the earth should cease to yield her fruits everything would stop. Agricultural quantities are so vast in the aggregate that apparently small savings of labor, resulting from improved methods or machinery, amount to sums so large, when applied to the whole aggregate, that we can hardly conceive of them.

We have a vast country, with every good gift, and our people have undertaken its development with wonderful energy and success. Although the most of the improvements heretofore made have not been the work of professional engineers, yet they are engineering works. It is therefore proper at this time to direct the attention of engineers to some of the things which have been done during the last thirty years in improving agriculture, that they may see what a field is here laid open to them.

Let us begin with the plow : That instrument, which having superceded the spade and the hoe, is at the foundation of all wealth ; for without the plow there can scarcely be any successful cultivation of the soil. The progress in civilization of different nations may almost be measured by the character of their plows. Many of the nations of the old world still work with such plows as were in use when our Saviour was born.

Up to the present century little improvement was made in this respect. Cast iron plows were then invented, but for a long time farmers would not use them, believing that they "poisoned the land." Improvements were slowly made until 1850, when the New York State Agricultural Society made a grand trial of plows, and found that there was 46 per cent. difference in the power required to do the same work with different makes of this implement.

At that time the cost of plowing in the United States was estimated at twenty millions of dollars. Hence, if the plow having the least draft had been universally used there would have been a saving of 8 400 000 dollars ; or, what would have been probably the case, the farmers would have plowed 113 000 000 acres without more expenditure of power than it did require to plow eighty millions acres. Great improvements have been made since 1850, and the saving derived from the plows now in use, over those of 1850, has been estimated to amount to 45 millions of dollars

annually. Yet the plow of the future has not been invented. The English have made progress in steam plowing by the system of stationary engines and wire ropes, which drag the instrument back and forth across the field, but with our rich soil and thin cultivation this system affords no economy to us over the plowing by horses. We still need a steam plow, perhaps a locomotive one, which shall cover more acres at less cost, and, if required, plow deeper and more thoroughly than the plows drawn by animals, and which shall not be constantly breaking down. The problem, so far, has not been solved. Here is a field for inventive engineers. They will find in Van Nostrand's Engineering Magazine for April, 1878, a capital account by Mr. D. D. Williamson, of what has thus far been accomplished in this country.

The largest single agricultural interest in the United States is the cultivation of Indian corn. The crop of 1877, the largest yet produced, was estimated at 1 342 558 000 bushels, worth, at 35.8 cents per bushel, $480 643 400. Under the old system a man could plant by hand three or four acres a day; now, with a two-horse check-rower planter, twenty acres can be planted in a day. As the planting season lasts about ten days one man can now plant over 200 acres instead of forty.

In old times corn was cultivated by the plow; then came the cultivator. It is estimated that by the use of this implement, as improved at the present day, a saving of five cents per bushel is made over the old method by cultivation by the plow. The saving for the crop of 1877 would therefore have been 67 millions of dollars. This is all due to the more complete pulverization of the soil.

Again: A man can shell by hand five bushel of corn, by working hard ten hours. Thirty years ago this was the only method in use. Now, two men with a machine driven by steam, can shell 1 500 bushels per day. It would take the entire farming force of the corn growing States, at least 100 days of steady work to shell the corn which they raise, if it were done by hand, and it is estimated that it would cost nearly as much to shell the crop as it now brings to the farmer.

Let us take up the wheat crop. It is estimated that the use of the improved seeder, which sows wheat, clover and phosphates all at once, and harrows at the same time, increases the crop of winter wheat at least one-eighth. This represents a saving of 37 millions of dollars.

But the greatest triumph of agricultural machinery is the self-binder

and reaper. A boy driving a pair of horses will reap and bind 15 or 20 acres per day.

One can see on the line of the Northern Pacific, a field of 7 000 acres, producing 154 000 bushels of wheat, at a cost said not to exceed 25 cents per bushel ; all cut, bound and threshed by this machinery. The aggregate saving of cost over the old fashioned methods by the sickle and flail, is estimated at one-third the value of the wheat crop, or 100 millions dollars annually.

Were it not for such inventions as these, and the cheapening in our modes of transportation, we should not have been enabled to compete with the cheaper labor in the basin of the Danube and the Black Sea, in supplying Europe with our breadstuffs.

The attention of this audience of Civil Engineers, is called to the fact, that the cotton crop of the South is yet sown, cultivated and picked by the old fashioned methods, which have scarcely changed in the last sixty years. Were the same inventive skill applied to this industry which we have seen has been applied to corn and wheat, the saving would be enormons.

Immigration has again set in to our shores. After falling off from 449 483 in 1872, to 149 020 in 1877, it has now sprung up again so that 21 094 immigrants arrived in March, and 35 181 in April of this year, at the port of New York ; and these people, most of them in the prime of life, each estimated upon landing to add $1 000, at least, to our National resources, need to be provided for, set down upon farms, and made useful to the country.

Enough has been said to show that this is a branch of engineering too important to be neglected, If Engineers desire to take a higher rank than they now occupy in this country, they must study out new paths for themselves, and be no longer men of routine, ordered hither and thither by promoters of schemes, and the magnates of Wall street.

Transportation of Meats.

The problem of cheaply supplying our cities with animal food, is an important question which is deservedly attracting attention. It is becoming evident that the Western plains and the adjacent territory are to become, if they have not already become, the cattle raising portions of the United States ; where meat will be produced more cheaply than in other parts of the country. The problem is how to convey the animals

to the point of consumption, from 500 to 1 500 miles distant if marketed here, or 4 500 miles away if exported to Europe.

Thus far two systems of transportation have been introduced. The first consists in shipping the animals alive on the hoof, to be slaughtered at the point of consumption. This is mainly done by railroads, and special cars are used for the purpose. The second system consists in slaughtering and dressing the animals, near the point of production, cooling the meat nearly to freezing point, down to the bone; and [shipping it in refrigerated chambers to the point of consumption.

I much wish that some member of this Society, shall study the relative advantages and economy of these two methods, as well as the appliances that have been used or proposed, and give us a paper upon this subject.

The Engineering Future.

Although during the past few years there has been a depression in the progress and undertaking of new enterprises, and a diminished demand for engineers, I do not believe that we are at the end of the great industrial movement which began with the steam engine. I think rather that we stand on the threshold of greater undertakings, and, perhaps, of inventions, which will mark epochs in civilization, and which, whether made here or in some other country, our engineers should be prompt to take up, to perfect, and to introduce.

There are signs that a new motive power will be invented, which shall be safer, of greater energy and less wasteful than steam. You know that chemists tell us that the theoretical energy of a pound of coal, varies between 8 and 11 millions of feet pounds, while we utilize with our best steam engines but from 3 to 11 per cent. of the theoretical value of the fuel. I think it not impossible, that we shall perfect methods of employing directly the gases, produced from our fuels (instead of using them to generate another gas out of water), and thus obtain better economical results than with steam. I know of several promising attempts in this direction,

And, with a new motive power, perhaps will come the solution of the last transportation problem which remains to be solved. I suppose you will smile, when I say that the atmosphere yet remains to be conquered; but wildly improbable as my remarks may now seem, there may be engineers in this room, who will yet see men, safely sailing through the air.

In making this review, I have gone over rather a wide field, and touched upon topics, which some of you, perhaps, may consider as foreign to our profession.

I have, however, but followed the European practice, and that especially of our early professional teachers, the English, who, mindful of the original distinction between the *civil* and military branch, recognize all makers of Marine, Telegraph, Gas, Mining and Agricultural *engines*, as Civil Engineers.

In this country, we have taken hitherto a somewhat narrower view of the province of the engineer. We think of him mainly as a builder of water works, canals, railways and bridges, and we underrate his importance as a builder and applier of machines.

In point of fact, the most important services which the world has received from our profession, have been rendered by the Mechanical Engineers. The men who have reduced the cost of iron and steel to less than half the prices which obtained half a century ago, who perfected the steam engine, who set it to drawing carriages over the land, and driving great ships through the sea, and who harnessed lightning to convey thought, are the men who have made the present development possible, and enabled us to build the public works of the country.

In Europe, the Civil Engineer is required to be much more than a mere designer and layer out of public works. Not only must he thoroughly understand the application of machinery, and be able to devise new methods, if necessary, but he is expected to be a business man, to act as an originator and promoter of new enterprises, as a director or superintendent of public improvements, and as an organizer of labor.

It is, probably, in consequence of that broader understanding of the field open to them, as well as the better organization of their professional societies, that the Civil Engineers have attained a higher position abroad than they have, as yet, in this country; and have attracted into their ranks the most enterprising and gifted men, who remain permanently in the profession; while with us, engineers, cease to be regarded as such by the public, when they achieve success, and become presidents or superintendents of public enterprises.

In France, the direction of almost all departments of public works, is in the hands of engineers, and two of them are members of the present ministry. In England, so great is the confidence that the public have in engineers, that they are constantly called upon to appear before com-

mittees of Parliament, thus coming into contact with the ablest men in the kingdom, to advise them concerning the merits of various propositions ; and no new scheme stands much chance of success unless it is approved by the leading members of the British Institution of Civil Engineers, which includes within its list, not only the names of all the eminent men in the profession, but also those of princes, kings, and an emperor.

And now, I suppose you will expect me to say a few words concerning our own Society. It is fairly prosperous. We have now some 600 members,* and while we have been hitherto gaining at the rate of about 30 a year, we shall probably increase by some 100 members this year.

The continued organization of engineers' clubs and societies in various cities, however, (three of them during the past year), and that of a general society of Mechanical Engineers, suggests that there is a want, which we have failed to supply, and raises the question whether our organization, which we have mainly copied from that of the British Institution, is entirely the best for us.

The vastness of our country, and the great distances over which our engineers are scattered, make it inconvenient for them to attend our meetings in New York, which seldom number more than 20 members ; while in England, the leading engineers are nearly all within a few hours ride from London, to which, besides, their duties constantly call them.

I believe our organization may be improved upon. We might have a larger number of meetings each year, away from headquarters in New York. The growth of the Society of Mining Engineers to some 900 members in 10 years, may have been partly due to this feature, which has also been adopted by the new Society of Mechanical Engineers.

We might also devise some method of affiliation with the Local Engineer's Clubs in various cities. Most of you remember, that an effort was made in 1873 and 1874, to organize local branches (Chapters, as they were then called), to the Society in various cities. The proposal was much opposed, by some of our oldest and most respected members, and was finally abandoned, mainly, as I believe, for want of an adequate plan.

If, however, we want to raise the professional standard and position, we need a closer union, and greater concert of action, than now obtain

* The British Institution of Civil Engineers numbered on July 2d, 1879, 3,578 members, and is increasing at the rate of some 150 a year. The average attendance at its meetings is 120.

among engineers in this country. A continuance of the present course of division and dispersion, will be certain to have the contrary effect.

I do not believe there is room in this country for more than one first-rate Society of Civil Engineers. It should, in my judgment, include all the men, eminent or rising, in the several branches of the profession, and so raise the professional standard, as to become an influence in society, and truly useful to the country.

Success will depend upon the adequacy of the plan. Let us, therefore, consider whether one can be devised ; and, always bearing in mind, in the words of Telford : "That talents and respectability are preferable "to numbers, and, that from too easy and promiscuous admissions, un-"avoidable, and not infrequently incurable, inconveniences perplex most "societies;" let us think, whether some changes in our organization, to be thoroughly examined and discussed before they are adopted, shall not raise still higher the standards of technical education, of working practice, and of professional honor.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CXCVI.

Vol. IX—July, 1880.

THE HUDSON RIVER TUNNEL.

By ARTHUR SPIELMANN and CHARLES B. BRUSH (Spielmann & Brush), Members of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, MAY 25TH, 1880.

With Discussion by ASHBEL WELCH, E. S. CHESBROUGH, JAMES B. EADS, JAMES B. FRANCIS, WILLIAM R. HUTTON and CHARLES B. BRUSH.

The Hudson River tunnel is being constructed by direct application of compressed air in accordance with the "Haskin" system of tunnelling in soft material.

Soundings were first carefully taken and the best location agreed upon. A shaft was sunk on the New Jersey shore near the river line, and from the side of the shaft the tunnel was started under the river on such a

grade as never to leave less than twenty feet between the bottom of the river and the top of the tunnel.

In some respects this work resembles that of Mr. Chesbrough at Chicago and Detroit.

As at Chicago, in 1869, a brick shaft thirty feet in diameter was first built on a shoe ; the material was taken out from beneath the shoe and from the interior of the ring, and as the shoe sank masonry was added above. As at Detroit, in 1872, it was determined to build two single track tunnels, instead of one tunnel large enough for a double track, for several reasons. The two single track tunnels require less excavation and brick work. The calculations show that to build a single double track tunnel twenty-four feet high and twenty-six feet wide in the clear under the river, would require walls three feet in thickness, and would necessitate for each running foot of the tunnel

28 cubic yards of excavation,
2,200 pounds of iron for the shell,
5,540 bricks laid in cement.

While to build two single track tunnels fifteen feet ten inches wide, and seventeen feet ten inches high in the clear, would require only two feet thickness of walls, and would necessitate for both tunnels

26 cubic yards of excavation,
3,000 pounds of iron for the shell,
5,040 bricks laid in cement.

In addition to its economy of material, the economy and ease of working a face at the heading of three hundred and forty-six square feet required in the single tunnels over that of seven hundred and fifty-four square feet as required in the double track tunnel, and the fact that the smaller tunnels are required to support eight feet less head of water and silt than would be the case with the larger tunnel, make the single track tunnel system in every way preferable for this work.

Unlike the Chicago shaft, however, the New Jersey shaft has been sunk sixty feet in depth instead of thirty feet, and the thickness of the walls at the bottom of the shaft is four feet instead of two feet nine inches. Unlike the Detroit work, this work requires no intricate system of timbering, and no drainage tunnel is proposed, it being kept entirely free from water by compressed air.

THE SHAFT.

Form	Circular.
Outside diameter bottom	38 feet.
Inside diameter	30 feet.
Depth	60 feet.
Thickness of wall at top	2 feet 4 inches.
Thickness of wall at bottom	4 feet.
Batter outside	20 inches.
Weight of shoe	24 tons.
Total weight of structure	1,340 tons.

THE SHOE WAS SUNK THROUGH

Loose ash filling	5 feet.
Tenacious silt	50 feet.
Sand	5 feet.

The shoe is made of ten inches by twelve inches yellow pine, bolted together by drift bolts in ordinary ship work style. It is four feet high and four feet wide on the top with a cutting edge of boiler iron. The brick work of the shaft was laid in Rosendale cement, except the false work on each side of the shaft, elliptical in form, twenty-four feet high and twenty-six feet wide, which was to be eventually removed to make way for the tunnel and approach. This false work was laid in common mortar and caused some trouble. During the process of sinking the shaft that portion of the false work on the east face was forced out of its position to such an extent as to require interior bracing to hold it in place, the projection at the top of the false work amounting to about seven inches, and running out to practically nothing at the bottom.

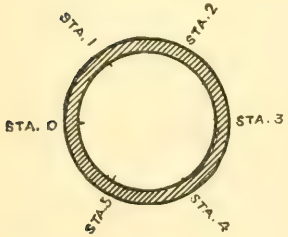
An hexagonal collar brace, of ten by twelve inch yellow pine, was finally adopted as being the most advantageous and as exerting an equal pressure at each joint. Four of these were placed in position, and were found to work very satisfactorily ; they not only answered the purpose of braces, but acted as well for floor timbers, supporting the series of platforms which were required from time to time.

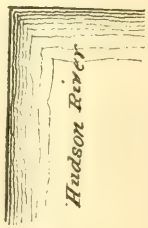
The shoe was placed in position November, 1874, after an excavation of about five feet below the surface of the loose filling, and the sinking of the shaft continued until December, 1874, when an injunction was obtained by the Delaware, Lackawanna & Western Railroad Co. against

the further prosecution of the work. Litigation continued until September 18th, 1879, when the work was resumed. At this date the shoe was about 14 feet below mean high water.

The settlement of the shaft was not uniform The greatest difference of level of the sides of the shoe amounts to one foot. This inequality was not due to want of homogeneity in the soil, but rather to external circumstances.

It was found that the hoisting engine by its vibrations caused that part of the sinking shaft nearest it to settle faster than the other part. The engine was thereafter moved from time to time, and the settlement became more nearly equal. The following table shows the actual settlement from day to day of the different sides of the shaft by giving in feet and hundreds of feet the depth of the shoe below mean high water at different dates.





1880.	STATIONS.					
September.	0	1	2	3	4	5
18	14.13	14.43	14.43	14.33	13.93	13.83
19	14.23	14.53	14.73	14.83	14.53	14.43
20	16.63	16.73	16.93	17.03	16.93	16.73
22	19.63	19.63	19.13	18.83	18.93	19.33
23	21.93	21.73	21.13	28.83	21.13	21.73
24	24.13	23.73	23.13	22.93	23.33	24.03
25	26.13	25.63	24.93	24.73	25.03	25.93
26	28.53	27.93	27.13	27.03	27.63	28.33
27	31.13	30.63	29.73	29.53	30.03	30.93
29	31.73	31.18	30.28	30.13	30.73	31.53
30	34.55	34.03	33.03	32.73	33.33	34.33

1880.	STATIONS.					
October.	0	1	2	3	4	5
1	36.47	35.96	34.95	34.54	35.08	36.13
2	38.05	37.58	36.51	36.03	36.50	37.56
3	39.08	38.68	37.53	36.98	37.43	38.52
4	41.82	41.54	40.43	39.81	40.15	41.52
5	44.11	43.92	42.82	42.15	42.42	43.41
7	47.00	46.91	45.86	45.16	45.36	46.28
8	49.14	49.07	48.00	47.26	47.42	48.36
9	49.24	49.19	48.11	47.38	47.54	48.47
10	49.33	49.27	48.22	47.50	47.67	48.67
11	49.96	49.91	48.91	48.22	48.36	49.23
15	50.32	50.28	49.31	48.67	48.17	49.59
18	52.07	52.10	51.23	50.57	50.63	51.39
25	52.77	52.82	52.01	51.41	51.47	52.15
28	53.46	53.43	52.74	52.27	52.42	52.96
29	53.56	53.53	52.77	52.43	52.48	53.16
30	53.89	53.84	53.20	52.77	52.95	53.49
31	54.07	....	53.38	52.95	53.19	53.64
November.						
3	54.38	54.37	53.70	53.37	53.45	53.95

*On November 3d, 1879, the shoe was in position fifty-four feet below mean high water, or sixty feet below the surface, a settlement of forty feet in forty days, or an average of one foot per day.

The sand bed on which the shoe rested was saturated with water. During the sinking of the shaft all the water that came in was easily pumped out with an ordinary hand pump, but when the sand stratum was encountered, water commenced to pour in at the rate of about two hundred gallons per minute. An Andrews' pump, capacity three hundred gallons per minute, and a Pulsometer, capacity one hundred gallons per minute, were used alternately to keep the water down while making the excavations.

The greatest difficulty was that the inflowing water carried with it both sand and silt, thus not only increasing the amount of excavation but undermining the soil surrounding the exterior of the shaft.

On November 3d, 1879, when the shoe was finally in position the work of putting in the concrete bottom commenced.

*November 1st, 1879, the writers were appointed engineers in charge of the work.

An open slat wooden curb four feet six inches in diameter at the bottom, two feet in diameter at the top, and four feet high, lined with dry brick, was first sunk to its full depth in a convenient portion of the bottom of the shaft, the bottom of the curb resting about two feet in a bed of gravel composed of stones about three inches in diameter. A number of pieces of second hand four inch iron pipe were then laid from this well radiating in such directions as to confine the water as much as possible in covered chambers.

On a small portion of the bottom, least exposed to the running water, a foundation of loose, dry stone, from 12 to 18 inches in depth, was roughly but securely imbedded. On this the concrete was placed in layers from 8 to 12 inches in depth. Another adjoining portion of the bottom was treated in the same manner, and thus the water was gradually all confined to the well.

The concrete as laid was 2 feet 6 inches thick in the centre, and from 3 feet to 3 feet 9 inches thick on the sides, the average thickness being about 2 feet 9 inches, the centre of the surface being about 2 feet 6 inches lower than the highest portions of the sides. About 90 cubic yards of concrete were laid, mixed in the proportion of one of cement, two of sand, two of stone, and one of gravel. Each batch furnished about 14 cubic feet, or 3½ barrels of concrete. 163 barrels of cement were used in mixing concrete, and 12 barrels were used neat for stopping bad leaks and floating the surface of the bottom after the concrete had been laid.

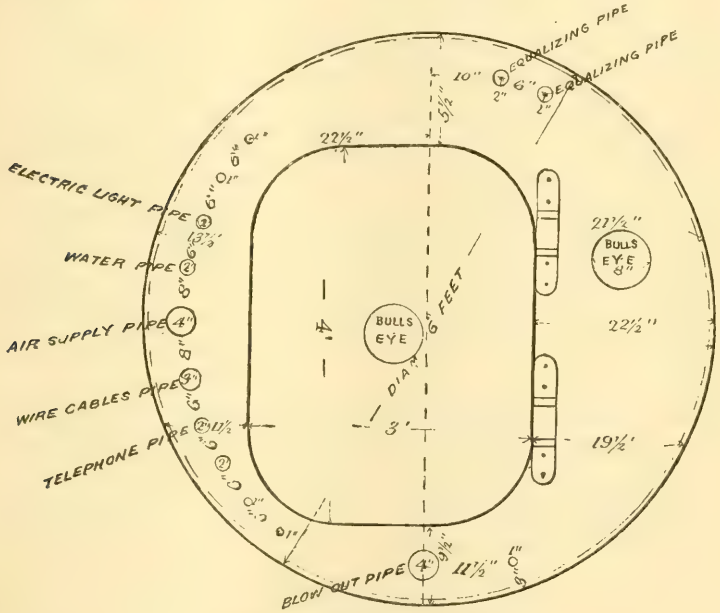
November 7, 1879, the concrete bottom was completed. Time occupied, 36 hours.

After the bottom was laid, the water continued to flow through the well at the rate of about 80 gallons per minute. It was found that the sand came through the well with the water, at the rate of about 4 cubic feet per day. The well was filled with dry stone, but this only partially retarded the sand.

A stand-pipe, 12 inches in diameter, was then carried up from the bottom of the well, for 25 feet, then a reducer for 5 feet 7 inches, then a pipe 4 inches in diameter to above the level of high water. The water rose in the stand-pipe to a level of 9 feet below the surface of mean high water, and then rose and fell in exact proportions, but not to the same extent as the tide in the river, the differences of level in the pipe being about one-third those in the river; this continued until the first rings of

the completed tunnel were built, as hereinafter explained, and the bed-sand struck.

As soon as this bed-sand was struck, the water came into the tunnel from the sand at the rate of about 5 gallons per minute ; the air pressure was then increased, and the inflow ceased ; the water in the stand-pipe, however, began to blow out with great violence, the spray being driven from 15 to 20 feet above mean high water. A cap was then put on the stand-pipe and the water confined. It has ever since been used as a reservoir, from which the water is drawn to mix the cement for the masons, and to dissolve the silt preparatory to blowing the latter out of the tunnel.



END VIEW OF AIR LOCK.

The air lock is entirely of wrought iron. It is horizontal, 6 feet in diameter and 15 feet long. The doors are 3 feet wide and 4 feet high. The shell is made of ⅜-inch boiler iron, the plates being 3 feet wide and

NOTE.—December 1, 1879, we secured the services as superintendent of Mr. J. F. Anderson to whom Mr. D. McN. Stauffer, C. E., and member A. S. C. E., has referred in his paper on compressed air in tubular foundations, and its application at South Street Bridge, Phila., No. CLXXII., and to whose experience, courage and endurance, a large portion of the success of the work is due.

extending over half the circumference without break. They are double riveted on the longitudinal laps and single riveted on the transverse laps, with ⅞-inch rivets two inches apart from centres, and all laps are carefully caulked. The heads and doors are ½ inch thick. Each head contains 13 pipes ranging from 1 to 4 inches in diameter, all of which run entirely through the lock. In addition one 6-inch pipe has been run through the tunnel end of the lock, emptying through the side of the lock into the bottom of the shaft. These pipes have been found to be very convenient, and are or will be used for various purposes, such as air supply, water supply, electric lights, telephones, blow-out pipes, etc.

There are four bull's eyes, one in each door, and one in each head at the side of the door; those on the sides have been found to be very convenient, but those on the doors are of no practical value for purposes of light. The glass is one inch thick and nine inchs in diameter, the exposed surface being 7½ inches in diameter. The door frame is of 4-inch angle iron, securely riveted to the heads. Each head has five 2-inch braces, 2 feet long, riveted to the shell. The door is braced by strap hinges 3 inches wide, and ¾ inches thick, extending all the way across the door at a distance of 10 inches below and above the top and bottom of the door, and by two pieces of 4-inch T iron, also extending entirely across the door at a distance of 1 foot 6 inches below and above the top and bottom.

The air-lock is used for the transmission of men and materials, but it has been found to be too small. Other air-locks will be built vertically between the shaft and the river, to receive the material, leaving the present lock for the men alone.

Excavation.

The material through which the tunnel is built is a tenacious silt, weighing about 100 pounds to the cubic foot. It seems to be impervious to both water and air, yet when thoroughly mixed with water, it becomes a semi-liquid mass, which is easily handled.

An opening was made in the side of the shaft to receive the air-lock at the top of the old false work, 23 feet below mean high water. When the silt was first exposed it was stiff, and comparatively dry. It could

be moulded like putty, however, and had the same moist feeling as that material.

After the silt in this opening had been exposed three or four days, it began to soften, and show a tendency to run. The air pressure was then put on, and this tendency was immediately checked.

The first excavation under air pressure was made December 28, 1879. The company hoped at that time to be able to build a single double track tunnel across the river of the same size as the approaches, to wit, 24 feet high, and 26 feet high in the clear. An opening was, therefore, commenced, by excavating around the exterior wall of the shaft, extending the heading a few feet from the shaft. The air escaped somewhat through the brick and between the soil and the wall. Timbering was resorted to to protect the roof, but on January 2, 1880, the excavation only amounted to 15 feet in width, 6 feet in height, and 4 feet in length.

No effort had been made during these four days to protect the surface of the silt from the effect of the air, and the result was peculiar. At first no effect could be observed, but after a few day's exposure little holes about the size of a pin began to develop. A day later slight cracks appeared, a day later these small cracks concentrated into several large cracks, and as the air passed up through them, lumps of the silt from a few inches to a foot in diameter, fell from time to time. At the end of the fourth day, these falls became more frequent, and half a day later the whole had gradually fallen.

We found that these cracks had extended upwards about two feet through the silt to the loose filling above, which had been carried down during the sinking of the shaft, and the water had commenced to flow freely through these cracks in the silt. The effect of water on this silt is different from that on ordinary clay ; the silt in this respect being similar to quicksand. Instead of remaining hard and lumpy, the material, when exposed to running water, dissolves and flows readily with the water.

These experiments gave a very fair idea of the materials to be handled and the difficulties to be encountered. On January 5th, 1880, work was recommenced.

Plates for an iron tube 8 feet long and 6 feet 4 inches in diameter were ordered, the plates to be half an inch thick, 2 feet 6 inches wide and 4 feet long, with 3 inch angle iron flanges rivetted to the four sides of the plate.

While these were being prepared, an excavation was made 30 feet in width, extending from the east side of the shaft about 20 feet towards the river and to a depth of 9 feet below mean high water. The material excavated was all loose ash filling. At the depth of 9 feet below mean high water canvas was carefully spread over the bottom of the excavation and carried a few feet up the outside walls of the shaft. Heavy timbers, thirty feet in length, were then laid across this canvas to hold it in position, and to assist in supporting the refilling which was immediately replaced.

While the roof was falling, on January 2d, the door of the air lock at the tunnel end was closed, and the debris kept it shut. By the use of an hydraulic jack, however, it was forced open about 10 inches, when the water came pouring through the partially open door at the rate of about fifty gallons per minute. Compressed air was then applied and the flow of water checked, the glass bull's eye in the door knocked out and through this opening sufficient material was excavated to enable the workmen to open the door.

On January 13th, 1880, the air was again put on at 8 A. M., and on January 16th, at 5 P. M., the first ring in the temporary entrance to the tunnel, 6 feet 4 inches in diameter and 4 feet in length was in position. At noon on the same day the second ring was commenced; at 9 A. M. on the following day it also was finished.

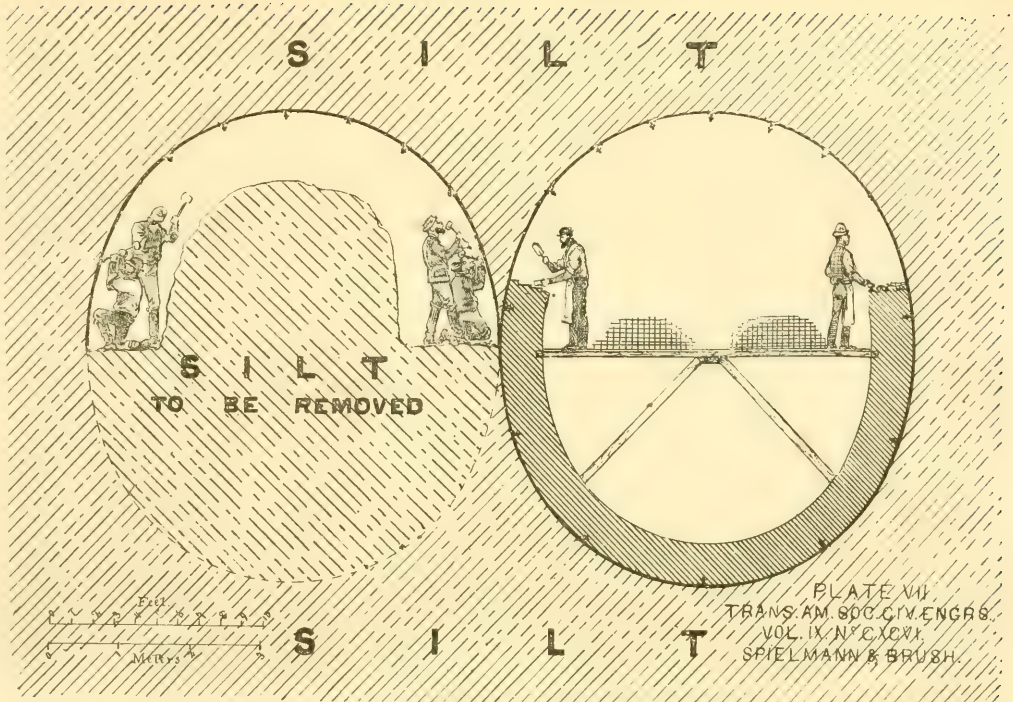
Iron Shell and Brick Lining.

A series of iron rings were then built 2 feet 6 inches wide, each succeeding ring increasing about 18 inches in diameter until the full diameter of the tunnel was reached. These rings were joined only at the top which descended so as to meet the proposed grade of the tunnel.

February 3d the 11 rings of the temporary work were in position, and the irregular spaces between the rings forming this entrance were temporarily filled in with concrete.

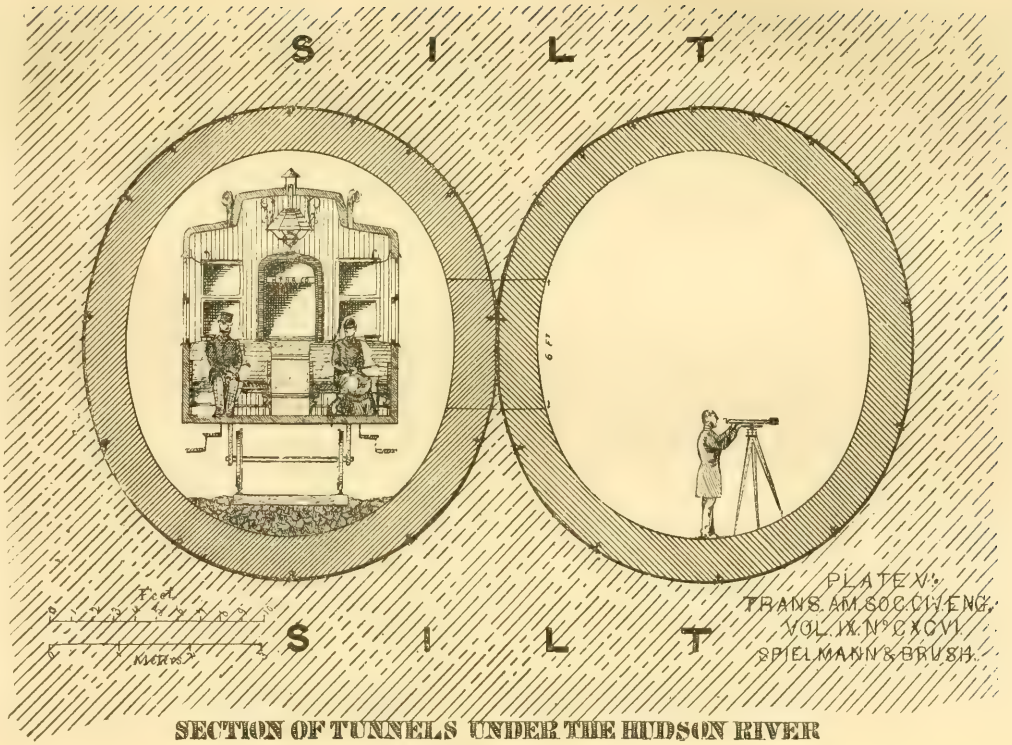
February 9th the first plate was placed in position in the most northerly of the permanent tunnels under the river, and since that time the work has been gradually systematized and has gone on rapidly and smoothly. During the first week the advance was hardly 1 foot per day, but at present the rate is 4 feet in each 24 hours.

The plan of advancing the work has been as follows :



SECTION OF TUNNELS UNDER THE HUDSON RIVER

IN PROGRESS



SECTION OF TUNNELS UNDER THE HUDSON RIVER

WHEN COMPLETED

To construct a series of iron rings each 2 feet 6 inches wide, well bolted together, and forming, when completed, an iron shell or tunnel in itself, then to follow up immediately with the lining of brick.

The rings in the permanent tunnel are composed of plates of wrought iron $\frac{3}{8}$ of an inch thick, and 2 feet 6 inches wide. There are 14 plates in every ring, the 6 top plates 3 feet in length and weighing about 170 pounds each, and the remaining plates 6 feet in length and weighing about 320 pounds each. These weights include the 3 inch angle iron that is rivetted on the sides and ends of each plate, the rivets being $\frac{1}{2}$ an inch in diameter, and placed 6 inches apart from centers. The plates are fastened together, so as to break joint, with $\frac{3}{4}$ inch bolts 9 inches apart from centres.

The bricks are hard burnt, of good quality, laid in the best Rosendale cement, in the proportion of 1 of cement to $1\frac{1}{2}$ of sand.

The Heading.

The heading is advanced as follows :

The face of the heading is always the exposed silt which is so stiff when under the air pressure, that it can be cut in benches as a series of garden terraces, and also into steps rising from one terrace to the other. An average slope of about 45° is usually left on this face, and the excavation for and the building of the rings always commence at the top of the tunnel. Usually 5 rings are building at the same time, each one of the 5 rings towards the rear being more nearly completed than the ring directly in front of it. The first 4 plates require some slight support, but the others are easily held in position by the air pressure, the bolting to adjoining plates, and the support received from resting the plates directly on a bed of the silt.

The bracing and timber ordinarily used in tunnelling are not required on this work. Some 4 x 6 inch timbers are thrown across from the end flanges of the iron plates in order to have a platform for convenience of access to the different parts of the work, but these are not relied upon as braces.

The support received from compressed air is not simply a theory. A short time ago when the heading was about 150 feet from the shaft, the bottom being 54 feet and the top 32 feet below mean high water, and a pressure had been used of 18 pounds per square inch, every thing

appeared to be working so well that it seemed as though a less pressure might suffice ; it was therefore reduced to 15 pounds per square inch. Within a few hours the timbers in use for platforms began to show signs of buckling, some of them bending as much as 2 inches. The pressure of 18 pounds was then resumed, and has since been maintained and no appreciable settlement of the plates has been observed up to this time.

The material excavated from the tunnel is not carried through the air lock. About half the silt is blown out of the tunnel. It is first reduced to a semi-fluid consistency by mixing 4 cubic feet of silt with 1 cubic foot of water, around the open mouth of a 6 inch pipe which extends from the tunnel through the air lock to the lower part of the working shaft. A stop cock on this pipe is then opened and the air in the tunnel allowed to escape and carry the silt with it. The remaining half of the silt is removed to the completed portion of the tunnel, where it will be allowed to remain until the approaches are completed, when it can be more economically removed by cars. There is still another reason for leaving this silt in the tunnel. It is known that a rod can be easily driven through the silt provided it is not allowed to remain at rest any length of time; when this occurs, however, the silt becomes so compact around the rod that in a few days it is almost impossible to move it. In many of the piers we have along our Jersey City and Hoboken shore fronts, the piles have been simply pulled down their full length, from 50 to 70 feet, by an ordinary tackle. They do not rest on hard bottom, and if they are a little too low for the string piece, are immediately raised in the same way, and in a few days the friction of the silt becomes so great that they cannot be moved. By leaving sufficient of the waste material in the tunnel so that the specific gravity of the iron shell and brick work added to that of the silt in the tunnel, shall equal the specific gravity of the total excavated material, there is no disturbance in the surrounding silt. The latter gradually settles around the outer portions of the tunnel and holds it fast in position.

Atmosphere in the Tunnel.

Records taken to date show that the thermometer in the tunnel always stands about the same, 72° Far.—whatever the temperature outside may be. At the bottom of the heading it is about 66°, and at the top 50 feet back from the silt it is about 76°. The air in the tunnel is very good and pure since the electric light has been introduced, but the

lime water test is still continually applied. Ventilation is provided by continually forcing pure air into the tunnel and forcing the foul air out with the silt through the blow-out pipe and through the pipe furnishing the air neccessary to run the force-pump, by lockage and to a slight extent by leakage along the bulkhead and the temporary entrance to the tunnel.

No injurious effect has been observed upon the workmen ; on the contrary, they seem to rather enjoy their daily air bath.

Care is taken to avoid the employment of men of irregular or dissipated habits and of men of over 50 years of age, and violent exercise is discouraged on their emerging from the lock.

The work is prosecuted day and night in three shifts of eight hours each, but at the end of four hours the men come out into the open air for meals or for changes of shifts.

The electric machine and lamp is furnished by the United States Electric Lighting Company, under Hiram S. Maxim's patents. It lights up the tunnel very brilliantly in the immediate vicinity of the lamp, but at a distance of from 75 to 150 feet, however, depending upon the clearness of the atmosphere in the tunnel, its illuminating power is to a great extent lost, and candles or other lights have to be used. About 2½ horse power is required to drive the electric machine supplying one lamp. The generator makes 1 050 revolutions per minute. When two lamps are running 5 horse power is required to cause the same number of revolutions. The Wallace coppered carbons are used in the electric lamp. They are 12 inches long and ⅝ inch in diameter.

The candles used are the ordinary coach candles, 7½ inches long and 1¼ inches in diameter, weighing about 5 ounces. By experiment last week it was found that these candles burned 1 inch in 1 hour and 40 minutes in the tunnel. The same candle was then lit outside of the tunnel and took exactly the same time to burn the next inch. This experiment was repeated with another candle and the same result obtained.

We have two air compressors which we use alternately. First, a double acting Clayton compressor with two air and two steam cylinders, each 10 inches in diameter, and 13-inches stroke. It compresses theoretically 2.53 cubic feet of normal air at each revolution, but, practically, about ⅓ of this amount is lost, and we only obtain 1.65 feet of normal air at each revolution.

Second, an Ingersol rock drill compressor, also double acting, but

with single cylinders, the diameter of the steam cylinder being 10 inches and of the air cylinder 12 inches, and the stroke of both 12 inches. Theoretically it compresses 1.57 cubic feet of air at each revolution, but as in the case of the Clayton there is here also a loss of about $\frac{1}{3}$, and we only obtain 1.05 cubic feet of normal air at each revolution. We are now delivering into the tunnel each 24 hours, about 83,000 cubic feet of normal air under a pressure of 18 pounds per square inch. In order to accomplish this, the average number of revolutions of each compressor, when running alone, is for the Clayton, 35, and for the Ingersoll, 55. This amounts to about 125 cubic feet of normal air per hour to each man at work in the tunnel. All this air is doubly washed, first as it is drawn into the air cylinders of the compressors, and again as it is passed through the water into the lower portion of the air reservoir.

About 11 horse power is required to run the Clayton compressor at the speed given above, and 8 horse power for the Ingersoll. Each require about 75 pounds pressure of steam on the boiler and 34 pounds on the piston.

Last week, telephonic communication was established between the tunnel and the surface. The Bell telephone and the Blake transmitter, are used, and so far they have worked very satisfactorily.

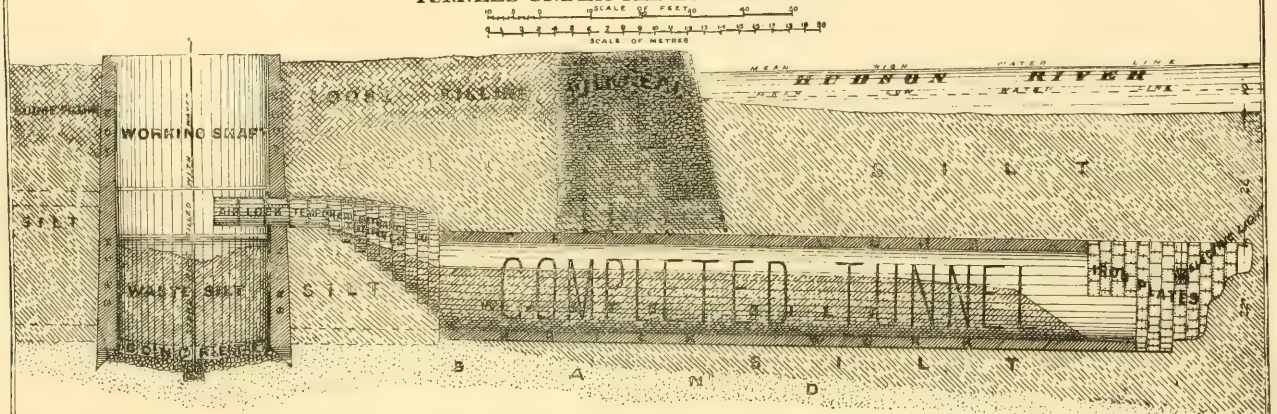
Up to this time the work has been confined to the shaft in Jersey City, the temporary entrance to the tunnel, and the north tunnel under the river, which latter has now been driven 230 feet from the easterly face of the shaft. It is proposed, however, to immediately commence the south tunnel and carry on both simultaneously, also to build the connection between the shaft and the double tunnels. The work on the New York side has necessarily been delayed on account of lack of the requisite legislative permission. This having been obtained it is proposed to start the shaft in New York without delay, and to work both tunnels from thence under the river to meet those coming from New Jersey, and to build the New Jersey and New York approaches.

Details of the cost of the work, the location of the New York approaches, and the uses to be made of these tunnels have not been considered in this paper, but they will be presented on some future occasion if so desired by the Society.

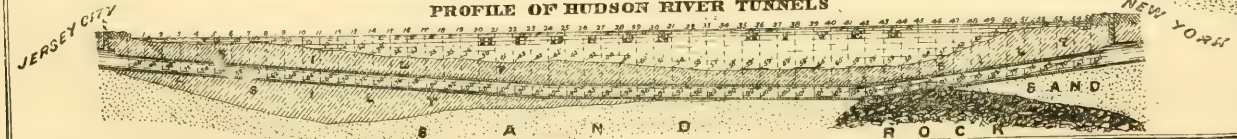
To Dewitt C. Haskin is due the credit of originating and carrying into successful operation this peculiar system of tunneling.

PLATE VIII.
TRANS. AM. SOC. CIV. ENGRS.
VOL. IX. N° CXCVI
SPIELMANN & BRUSH

SKETCH SHOWING
THE WORKING SHAFT IN JERSEY CITY & THE WORK IN PROGRESS ON THE
TUNNELS UNDER THE HUDSON RIVER



PROFILE OF HUDSON RIVER TUNNELS



Discussion of the above Paper at the Twelfth Annual Convention.

James B. Eads in the Chair.

The Chairman.—Gentlemen of the Convention, a discussion of this paper is now in order.

Ashbel Welch.—I would like to ask Mr. Brush whether the water that rises and falls as the tides rises is salt or fresh ?

Charles B. Brush.—The water is brackish.

E. S. Chesbrough.—I would like to ask how often soundings were taken across the river ?

Charles B. Brush.—Every 100 feet.

E. S. Chesbrough.—I would like to know also if the soil is uniform silt.

Charles B. Brush.—It appears to be. I will state that perhaps I am answering somewhat hastily in regard to these soundings. They were taken by another party during 1875. I have tested the depths of water since that time in various places—made rough tests—so that I might be sure the original soundings were approximately correct. I have not made a complete series of borings myself as yet.

The Chairman.—I would like to inquire what is the difference in the pressure of the water and the compressed air ? I understand that 18 pounds is all you use. The weight of water, due to the height above the place that you are operating, is not balanced by 18 pounds, I think ?

Charles B. Brush.—No, sir ; it is not. I have not made an exact calculation at this particular point. We found, however, that it was not necessary to use the amount of air sufficient to support a column of water equal in height to the depth of the tunnel, on account of the tenacious character of the silt itself.

The Chairman.—What is the depth you are working at now ?

Charles B. Brush.—The bottom of the tunnel is 58 feet below mean high water, and height of the tunnel is practically 22 feet, thus leaving 36 feet overhead, 10 feet of which is water and 26 feet silt.

The Chairman.—58 multiplied by the decimal .44 would give the pressure of water then.

Charles B. Brush.—Yes.

James B. Francis.—How does this material differ from clay ? It is

called silt, and has some of the characteristics of clay ; I would like to know the distinction ?

Charles B. Brush.—As we said in our paper, in some respects it resembles quicksand ; when water is applied it commences to dissolve, and is easily blown out of the tunnel. Clay, on the contrary, does not readily dissolve, water runs over it, and in this respect there is a difference.

The Chairman.—Does not the word "silt" comprise all fine silty matter which is carried in suspension in rivers ?

Charles B. Brush.—I presume it does. We use the term as the best to apply to the material. It is a deposit that is made, the accumulation of ages, from the flow of the river. I know of no better term.

The Chairman.—It is that portion of alluvium which is distinct from gravel and boulders ?

Charles B. Brush.—Yes.

The Chairman.—A material that is moved by rivers ?

Charles B. Brush.—Yes.

The Chairman.—That is my understanding of it, but I am not sure that I am right.

Charles B. Brush.—Yes. I did not intend in the term that I employed to cover sand or gravel or anything of that kind.

Ashbel Welch.—There is this marked distinction, sir, between silt of that neighborhood and clay ; I have put gravel, heavy gravel, upon this silt ; it has sunk through it 70 feet down to the rock. I have put the same gravel on ordinary clay, and it would not sink at all. (A specimen of the silt referred to was shown to Mr Welch, who said,) "Ah, it is an old acquaintance of mine."

E. S. Chesbrough. – I would ask Mr. Brush if he has tried whether a man can run his hand or arm through this silt up to the shoulder with comparative ease.

Charles B. Brush.—He can do that in the surface of the silt on the bed of the river but not below it. Our experience with this silt is a little different from that of Mr. Welch. We find that as soon as heavy filling, such as gravel, is put upon the silt, the silt is compressed and the gravel sinks. We have never found, however, that the heavy filling went through the silt to the hard bottom ; it always sank until the compressed silt was sufficient to uphold the weight above it ; it has not been our experience in this particular silt to have the heavy material go down

through it. In filling in the streets, over the salt marsh between the Palisade Ridge and the upland portions of Jersey City and Hoboken, we encounter this silt from 20 to 100 feet in depth. We find that the filling on these streets has sunk from 10 to 30 feet in depth. The sides of the silt are forced up and the heavy filling sinks down until the specific gravity of the two are equal, and then it stays there. In such cases the silt is compressed and becomes very hard indeed. I recall a case in point, the plank road from Hoboken to Jersey City. This road was built some 100 years ago. A light filling was put on and it sank a short distance ; from year to year more filling was put on, which sank down about 20 feet in the deepest portions of the silt. In one part of the road where the silt was from 15 to 20 feet in depth and where the filling had sunk from 6 to 8 feet, we opened a trench for the purpose of building a sewer ; after cutting through the filling, the silt was found to be so hard that we actually had to use picks to get it out. So also with the silt that we are meeting at the tunnel heading, it is absolutely impossible to run the arm into it, as Mr. Chesbrough suggests. On the contrary as you strike it, it gives out something like a ringing sound, and it is sufficiently compact to enable us to cut steps and terraces in it.

Ashbel Welch.—I quite agree with Mr. Brush ; the only difference between us is this. I suppose on a street 40 feet wide where the weight is put on equally, it will compress as he says and go down to a certain distance and stop, but the case I speak of is a narrow ridge of gravel, put that on and it will go down to the hard bottom, and if in filling a street we fill one side too much, that side will sink down and become unequal.

E. S. Chesbrough.—My reason for asking the question with regard to the ability of a man to put his arm into the silt is because as long ago as 1864, I supposed it might be possible to do what Mr. Haskins now appears to have succeeded in doing, in going through that silt. I had charge of a work in which I feared that difficulties of that kind might occur, and that it might be necessary to resort to the pneumatic process, and I then thought it might be possible to use it horizontally.

The Chairman.—You allude to the Chicago Tunnel ?

E. S. Chesbrough.—Yes, sir; the first one. But I found in very soft clay, where a man could run his hand and arm to the shoulder in it, there was no great difficulty in going through it, if the manager was careful and if all the workmen were on the alert, and every precaution

was taken to secure the work as they advanced, but if there was any quicksand, in a short time the ground would become, as they say, demoralized, and then it was exceedingly difficult to go on with the work. I had occasion a few years ago to try the horizontal pneumatic process, as I might call it, that is, the pneumatic work horizontally in what I would call slush. It was a perfect failure, and we came very near losing the men who were under the air-lock. It is for this reason that I feel such an intense interest in this work. I know that it is possible to go through very soft ground if the men, the engineers and all concerned are very careful to secure everything as they go, but if the ground happens to be very watery, very soft, or as I would call it "slushy," I have doubted whether the pneumatic process would be successfull. Still I know an engineer ought not to call anything impossible, and therefore I have looked with great interest to the labors of our friends here in the Hudson River Tunnel.

Charles B. Brush.—I would say that the slushy material through which we had to go at the top is entirely different from that which has been spoken of. For the space of a few feet on the top of the river it is soft for 3 or 4 feet perhaps, but beyond that it begins to grow quite consistent, and when we get down 15 to 20 feet we find a very stiff and tenacious bed of silt, and this continues all the way across.

William R. Hutton.—My notes on electric lighting are now more than a year old, and probably contain nothing new to you. I give some points referred to in a conversation with Mr. Brush, in case they may be of use.

A single light from a Gramme Machine, requiring 2½ horse power, lights in the open air a radius of 100 metres. A factory room 5 metres high, 24m. wide, 42m. long, containing 160 looms, is thoroughly well lighted by 6 Gramme lights, the light being reflected from a smooth white board ceiling ; having this advantage over gas, that the colors are not affected by it, and the different shades can be matched as well by night as by day.

One such light is sufficient for 500 sq. metres, of shops where minute work is executed, 500 to 1000 sq. metres of machine shop, 2000 sq. metres of out door work, earth-works, masonry, &c., &c.

When it is necessary to throw the light in one direction only, through an angle not greater than 180°, the diffuser designed by Van Malderen may be used ; its a parabolic mirror—the light in the focus—the front

closed a short distance from the focus by a dead glass, which receiving the parallel rays from the reflector, enlarges and diffuses them so as to illuminate all the space in front of it.

At the railroad station "du Nord" in Paris, the light proper is concealed from view in the hall by an inverted cone of ground glass, which reflects the arrested rays towards the ceiling along with the other rays. The ceiling being white, a diffused and nearly vertical light is distributed through the room.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CXCVII.

Vol. IX.—July, 1880.

AMERICAN NATURAL CEMENT.

By F. O. NORTON, Fellow of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, MAY 25TH, 1880.

In the course of a large number of experiments made upon the strength of cements, the writer has obtained certain comparative results which he has been requested by a number of the Members of this Society to present at this time.

The experiments referred to were made daily during the season of

1878, at the works of the writer, and show the results from breaking 5 824 test briquettes. The results of a portion of the test work in 1879 are also presented. It may be proper to refer for a moment to the circumstances under which this large number of tests was made.

For many years the manufacturers of the American cements sold under the general name of Rosendale cement, had permitted the standard of their productions to run very low. There was an active demand for cement and there was not, until within the last eight years, that care in selection or knowledge of appliances for testing on the part of large users of cement which now, fortunately, more or less exists. The introduction of the foreign Portland cement, at about that period, afforded an article, of course at a much greater price, but also of decidedly better strength than the low grades of American cement which were really the majority of those then in the market.

Since that time there has been a marked improvement in the quality of the Rosendale cements, effected by care and improved appliances in their manufacture.

The writer knows that a high standard for American cements can be secured, but only by determined effort and careful attention. Unfortunately there is to-day considerable cement of a very inferior quality offered as Rosendale cement, much to the disadvantage of the effort to maintain a standard of high strength.

The principal deposit of the magnesian lime-stone producing a cement possessing hydraulic energy occurs in the Town of Rosendale, Ulster County, New York. It was first brought into use about the year 1823, in the construction of the locks and other masonry of the Delaware and Hudson Canal, which passes through that county. Its production has gradually increased until there are now made from one million to one million and a half barrels in each season, of about eight to nine months, or during the period of navigation on the Hudson River between Rondout and New York. It is the chief industry of a large section of country, its reputation is extended and it is sold in most of the large markets of the United States.

In the management of one of the large works engaged in quarrying and manufacturing this cement, the writer instituted the system of tests referred to, for the purpose of securing uniformity in the product of those works, and of making sure that the standard of the cement made should be what was desired.

These tests were made daily at the works at Binnewater, Ulster county, New York, during the season of 1878, beginning April 1st, and ending November 30th, a period of eight months.

At several times each day a number of test briquettes were made from the cement manufactured during that day. These briquettes were mixed in two ways; namely, for one set the cement was mixed with sufficient water to form an ordinary stiff mortar which was pressed into the moulds with a trowel and smoothed off; for the other set a very dry mixture was made, following the formula adopted by J. Herbert Shedd, member A. S. C. E., in making his experiments. Both mixtures were left in the moulds a few minutes, and were then pressed out with a wooden plunger upon a sheet of tin or sheet iron, and left in the air for thirty minutes; they were then put in water and left in water until broken. The temperature of the water either for mixing or in the setting tanks was not closely noted, but spring water was used, the temperature of which varies very little during the whole year. In some cases the water in the setting tanks was changed frequently, in some cases very seldom, while some of the briquettes were kept in a flowing spring for twelve months. The results in each of these cases did not materially vary.

From each day's production one briquette of the wet mixture and one briquette of the dry mixture were broken at intervals after the mixing of the briquette, of respectively twenty-four hours, seven days, one month, two months, three months, four months, five months, six months, seven months, eight months, nine months, ten months, eleven months and one year.

There were during the season, the kilns not being drawn on Sunday, twenty-six briquettes of each mixture tested for each of the above periods, including the one year test or for the eight months of the season's production, 208 tests of each mixture for each of the fourteen periods, making 5 824 briquettes made and broken of the season's production. In other words, there were each month twenty-six days' production, and fourteen briquettes of each mixture each day, giving the total for the eight months of 5 824.

The curves presented have been drawn from the tabulated results, precisely as recorded by the testing machine, with no omissions or alterations. Many briquettes broke low on account of mechanical defects in their construction or from cross strains resulting from unevenness in their form, probably due in many cases to slight settling of the mortar

after removal from the mould and consequent imperfect fitting in the clutch. Some variations in the results are also probably due to inequalities in setting, to the season of the year when the briquettes were mixed, and to the temperature of the water or air before breaking. Certain individual results shown in the tables are worthy of attention, but of course the main interest lies in the general and average results shown by the curves presented herewith, which are given in accompanying* Plate IX. These prove conclusively that a cement of high standard strength can be continuously produced in large quantities from the quarries in Ulster county, New York. This, of course, can only be done by proper selection of the stone and careful attention to the manufacture. Even the minimum results are higher than has generally been supposed practicable averages for Rosendale cement.

The writer considers these 5 824 specimens, fair samples of the production of the Binnewater works during the season of 1878, amounting to nearly 150 000 barrels of cement.

An incidental result of these tests is of great interest. There has been a general impression that the use of a very small amount of water in mixing cement gave greater resulting strength than when sufficient water was used to form a paste of the consistancy of stiff mortar. The tests here recorded and shown on Plate IX, prove that the dry mixture does give decidedly higher tensile strength in 24 hours after mixture, and that it continues to be stronger than the stiff mortar for some three months. But after that time the reverse becomes true : the curve of strength of the stiff mortar rises to and passes above that of the dry mixture and the strength of the cement mixed as a stiff mortar continues greater than that mixed with very little water, and this is the case continuously thereafter.†

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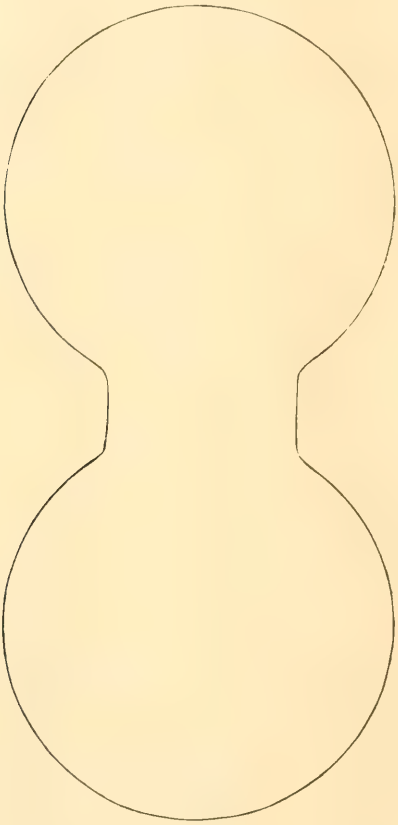
* Tables giving the record of tests for each day, and also monthly plates giving the curves of these tests as drawn from the records were presented with this paper. The published Plate (IX.) shows the average curves for the season. The publication of these tables of daily tests and the monthly plates is omitted for the sake of brevity.

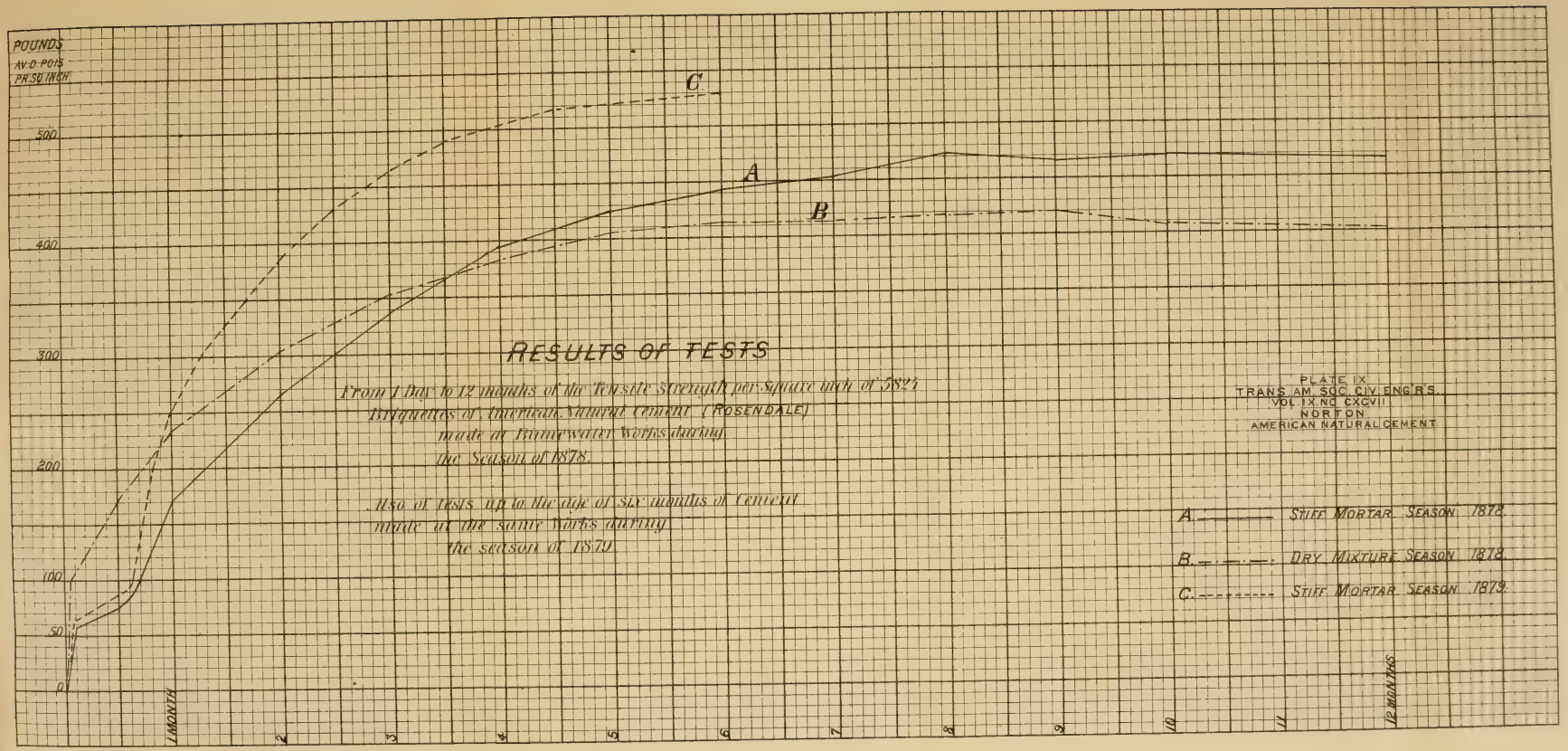
† The expression "stiff mortar" does not refer to thin mortar, but to a mortar made with only such an amount of water as to secure a stiff, plastic paste similar to plasterers' mortar. Water used in excess will certainly weaken the mortar.

The shape and size of the brass mould used is as shown in the accompanying sketch. The breaking area is one inch square.

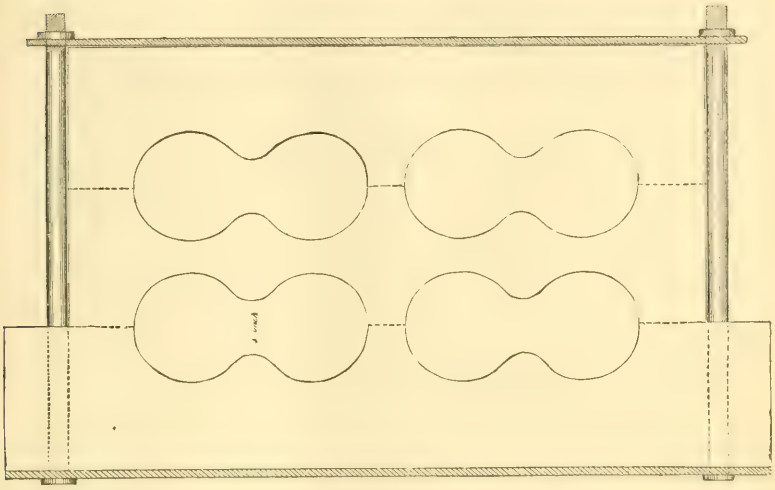


The machine used for breaking was built by Riehle Brothers, of Philadelphia, who exhibited its mate at the Centennial Exposition.

During the year 1879, a mould was used producing a briquette of the same form and size as those of 1878, but this mould was made of wood


POUNDS AVOIRDUPOIS PR SQ INCH
500
400
300
200
100
50
0
C
A
B
1 MONTH
2
3
4
5
6
7
8
9
10
11
12 MONTHS
RESULTS OF TESTS
From 1 day to 12 months of the Tensile Strength per Square Inch of Briquettes of American Natural Cement (ROSENDALE) made at Rainwater Works during the Season of 1878.
Also of tests up to the age of six months of Cement made at the same Works during the season of 1870
PLATE IX
TRANS AM SOC CIV ENG'R'S
VOL IX NO CXCVII
NORTON
AMERICAN NATURAL CEMENT
A. STIFF MORTAR SEASON 1878.
B. DRY MIXTURE SEASON 1878.
C. STIFF MORTAR SEASON 1879.

and was constructed so as to be unlocked and moved away from the briquette. (See sketch.)



This obviated the necessity for pushing the briquette out of the mould, and also permitted its remaining in the mould longer than with the metal one. The result has been greater uniformity in the form of the briquette, more accurate fitting in the clutch, and consequently less liability to cross strains. During 1879 the tests were made upon briquettes of stiff mortar only, under the same general method as has been described for 1878. The production of the works during the season of 1879, was about 170 000 barrels. The curve of results of tests of cement made in 1879 upon briquettes up to the age of six months, from this wooden mould (Curve B, Plate IX.), shows the advantage of this improved method of forming the briquette. The cement tested is believed to have been of the same general average quality as that of 1878.

Referring now to the general results of the tests of this American cement as given herewith, and comparing them with the tests of other cements, as for example, the foreign Portland, a comparison can be made as to the effective and economical use of these cements for various purposes.

Very full tests have been made of various brands of Portland cement,

notably by Mr. John Grant, in London, from 1859 to 1868. Results from these tests, running from seven days to seven years are shown in the accompanying table, which is from the paper by John Grant, Trans. Inst. C. E. London :

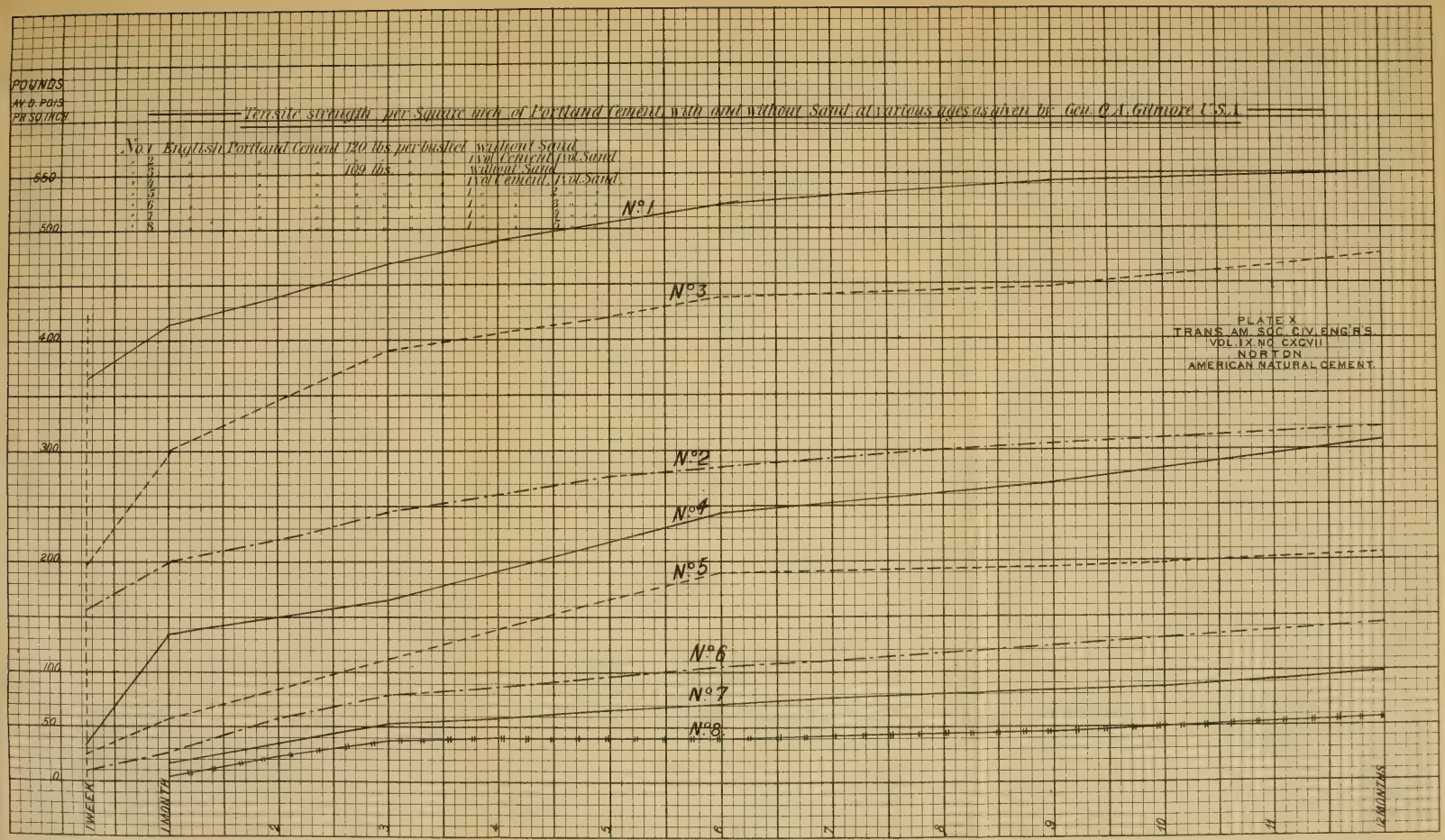
PORTLAND CEMENT.

Age.	Neat cement, average breaking test of ten experiments. Lbs. per square inch.	One of cement to one of sand, average breaking test of ten experiments. Lbs. per square inch.
7 days	363.1	157.0
1 month	415.9	201.1
3 "	469.3	243.3
6 "	522.9	284.6
9 "	542.0	307.7
12 "	546.5	317.6
2 years	588.8	351.2
3 "	584.2	348.8
4 "	583.4	363.6
5 "	580.4	364.9
6 "	581.3	364.2
7 "	589.9	383.8

The strength of Portland cement, unmixed with sand, is, of course, very great. It developes a large proportion of its ultimate strength in the first seven days, say from one-half to two-thirds.

Rosendale cement of the best qualities developes great hydraulic energy in twenty-four hours, being at that time equal to the Portland. The Portland then gains very rapidly upon it up to seven days, the difference between the two then being the greatest; at the end of a month, however, the strength of the Rosendale cement begins to approach nearer to that of the Portland, and the difference between the two seems to be continually reduced after that time, this referring to mixtures of pure cement.

For practical purposes, however, neither of the cements is generally used without an admixture of sand. The addition of sand to Portland cement reduces its strength rapidly, as is shown by the curves on Plate X. These curves are taken from the work on Coignet Beton, by Gen. Q. A. Gillmore, Member A. S. C. E.


POUNDS
N.B. POIS
PR SQ INCH
Tensile strength per Square inch of Portland Cement with and without Sand at various ages as given by Gen. Q.A. Gillmore U.S.A.
Nov. English Portland Cement 120 lbs per bushel without Sand
2 " " " " " 109 lbs. " " " " " 1 Vol Cement 1 Vol Sand
3 " " " " " " " " " " " " without Sand
4 " " " " " " " " " " " " 1 Vol Cement 2 Vol Sand
5 " " " " " " " " " " " "
6 " " " " " " " " " " " "
7 " " " " " " " " " " " "
8 " " " " " " " " " " " "
550
500
400
300
200
100
50
10
N°1
N°3
N°2
N°4
N°5
N°6
N°7
N°8
1 WEEK
1 MONTH
2
3
4
5
6
7
8
9
10
11
12 MONTHS
PLATE X
TRANS. AM. SOC. CIV. ENG'RS.
VOL. IX. NO. CXCVII
NORTON
AMERICAN NATURAL CEMENT.

This reduction of strength is in round numbers, as follows :

1	part of sand	gives	mortar	$\frac{1}{2}$	as strong as	pure	cement.
2	"	"	"	$\frac{1}{3}$	"	"	"
3	"	"	"	$\frac{1}{4}$	"	"	"
4	"	"	"	$\frac{1}{5}$	"	"	"
5	"	"	"	$\frac{1}{6}$	"	"	"

The reduction of strength of Rosendale cement by the admixture of sand seems to be somewhat less. The strength of a mortar formed by the mixture of one portion of Rosendale cement with one portion of sand has been tested, and the result of these tests is shown in Plate XI. The strength of the mortar of Portland cement in the proportion of one of cement to two of sand is, at the end of six months, say 224 pounds to the square inch, also shown in Plate XI.* The strength of a mortar of Rosendale cement in the proportion of one of cement to one of sand is, at the end of six months, say 257 pounds to the square inch.

Careful experiments made by General Gillmore, and published in the Appendix to the last edition of his treatise on "limes, hydraulic cements and mortars," give the quantities of mortar produced from the mixture of cement, sand and water, in various proportions, and using different kinds of cement. Adopting these results, and assuming the cost of the Rosendale cement at $1.10 per barrel, and the best English Portland at $3 per barrel (the market prices May, 1880), and the cost of sand at five cents per barrel, we find that a mortar of Portland cement in the proportions of one of cement to two of sand† will cost per barrel $1.22.

We also find that a mortar of Rosendale cement in the proportions of one of cement to one of sand will cost $0.68‡ per barrel.

Summarizing the comparison, we find that a mortar of Rosendale cement in the proportions of one of cement to one of sand has a tensile strength of 257 pounds to the square inch, and costs $0.68 per barrel; and that a mortar of foreign Portland cement, in the proportion of one of cement to two of sand, has a tensile strength of 224 pounds to the square inch, and costs $1.22‖ per barrel.

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* Clarke's Experiments—Boston sewerage.

† One barrel Portland cement and two barrels of sand give give 2.54 barrels mortar.—Gillmore.

‡ A mortar made from American Portland cement (at a price of $2.50 per barrel) in the proportion of one of cement to two of sand will cost $1.02 per barrel.

‖ A mortar of American Portland cement in the proportions of one of cement to two of sand has a tensile strength of 192 pounds to the square inch, and costs $1.02 per barrel.

Therefore, the mortar of Rosendale cement, one to one, is 34 pounds per square inch stronger, and $0.54 per barrel less expensive than a mortar of foreign Portland cement one to two.

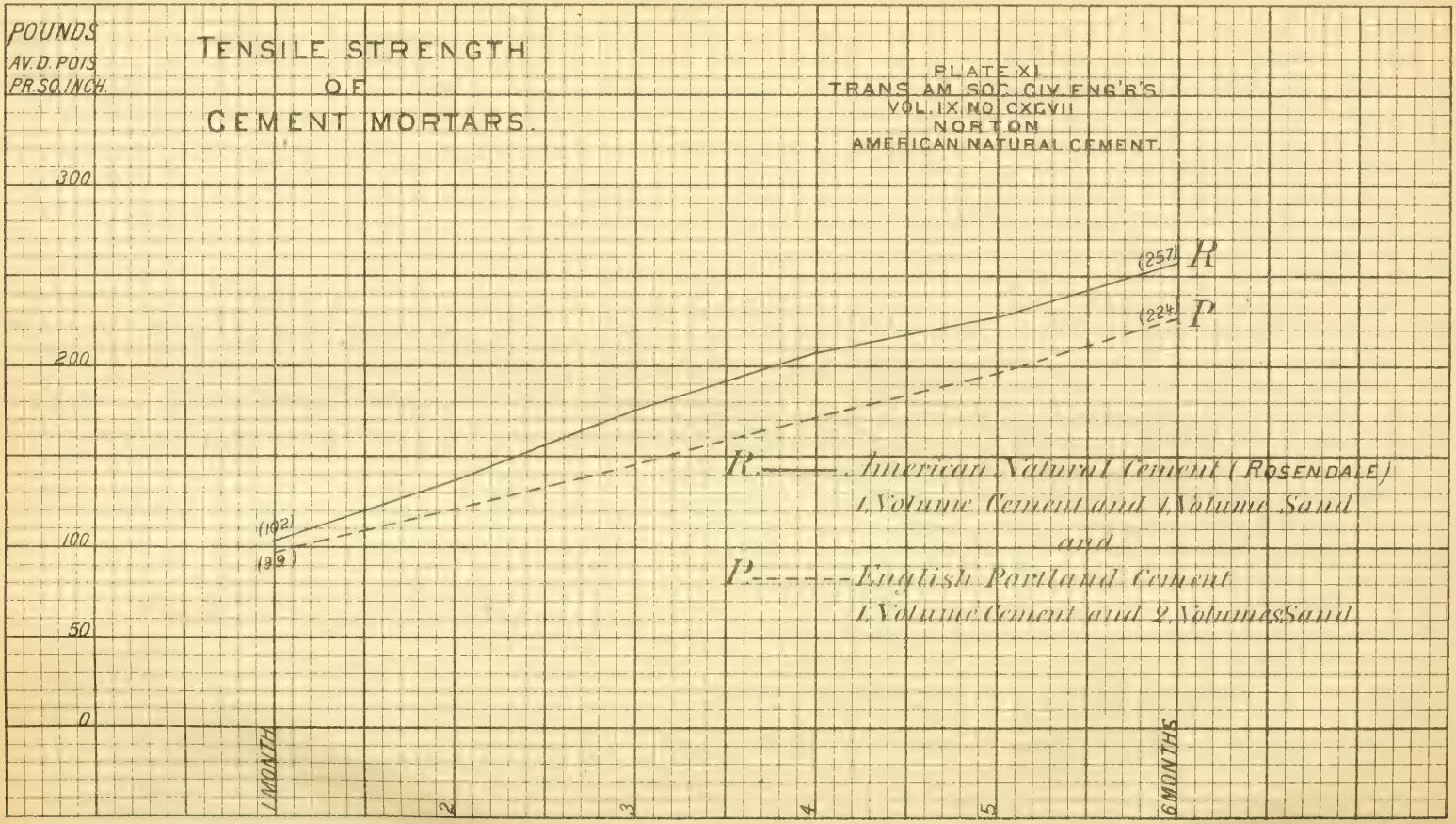
This seem to show that for all uses which will be served by a mortar of the tensile strength of 257 pounds per square inch, the Rosendale cement is economical.

The remaining question is, whether this mortar of Rosendale cement, one to one, is strong enough for the practical purposes to which it may generally be applied.

The facts which answer this question are that for fifty years past, and up to within a very short time *all* the important masonry in this country has been laid with American cement. The great fortifications on the coast, the Croton Aqueduct, the Boston Aqueducts, both old and new, all the government dry docks, the light-houses, the locks, culverts and aqueducts on the Erie and other canals; all the masonry of railroad bridges, viaducts and culverts, the sewers of our cities, the masonry of our gas-works, many hundreds of miles of wrought iron water-pipe lined and laid in cement; the mills and mill dams in various localities; in fact, nearly all the masonry built under water and out of water in the United States up to within a few years has been constructed with American cement.

The standard of strength for American cement during most of these years past was not as high as it now is, and only in specially important situations was the mortar made as rich as one to one.

The result of this use of American cement has been very generally satisfactory. As a proper economy in the use of the materials of construction is one of the essential elements of good engineering, the writer has ventured to submit these somewhat extended tests, made originally entirely because he believed that, as a manufacturer of cement, it would be in all respects advantageous to improve its quality and maintain a high standard for its strength. He has ventured also to present to the Society some deductions which seem to fairly follow the results of the tests.


POUNDS
AV. D. POIS
PR. SQ. INCH.
TENSILE STRENGTH
OF
CEMENT MORTARS.
PLATE XI
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. IX. NO. CXCVII
NORTON
AMERICAN NATURAL CEMENT.
300
200
100
50
0
(257)
R
(224)
P
(102)
(39)
R.——. American Natural Cement (Rosendale)
1 Volume Cement and 1 Volume Sand
and
P.——. English Portland Cement
1 Volume Cement and 2 Volumes Sand
1 MONTH
2
3
4
5
6 MONTHS

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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(Vol. IX.—July, 1880.)

DISCUSSION

By ASHBEL WELCH, Member of the Society, upon Paper CLXXXIX.

THE ENGINEERING PROBLEMS INVOLVED IN THE PROPOSED IMPROVEMENT OF THE ERIE CANAL, BY INCREASING THE DEPTH OF ITS CHANNEL ONE FOOT.*

I wish to call attention to a single point, suggested by Mr. Sweet's paper, giving experiments on the resistance to the motion of boats in a canal. He cites a formula of Du Buat, which, if I understand it aright, fails to take into consideration a very material circumstance. It makes the resistance of the vessel dependent on the relative areas of the immersed section of the vessel, and of the cross section of the channel, without taking any notice of the form of the channel, or of the vessel.

If you watch a boat passing through, and very near one side, of a lock or aqueduct much wider than the boat, you will see that the cur-

* Paper CLXXXIX, by E. SWEET, Jr., Member A. S. C. E. Vol. IX. March, 1880.

rent running in the direction opposite to that in which the boat moves, is several times as great through the narrow space, as through the wide one. So where the bottom of a boat is close to the bottom of a channel. the backward current under the bottom is vastly greater than that between the boat and the more distant boundaries or sides of the channel. This is shown by the force with which the water boils up under the stern, and by the coarseness of the particles of sand torn by the violence of the current from the bottom, and thrown up in the wake of the boat.

By the formula of Du Buat, unless I misunderstand its conditions, the resistance is assumed to be as the square of the velocity of the whole amount of the water flowing backwards past the boat, that is, as the square of the average velocity. But if this whole amount is divided up into different currents, with different velocities, the sum of the squares of the velocities of these different currents multiplied by the amounts of surface whose friction must be respectively overcome, will be quite different from the square of the average velocity of the whole multiplied by the whole amount of resisting surface.

Suppose a flat-bottomed, vertical sided boat, 20 feet wide, drawing 5 feet of water, and so having an immersed sectional area of 100 square feet, is moving 3 feet per second through a channel 6 feet deep, having 400 square feet sectional area, making the sections as 1 to 4. Then the wet perimeter of the boat will be 30 feet, and that of the channel, supposing its slopes are 1 to 1, not quite 78 feet. Then the average velocity of the counterflow, as I used to call it, required to send the water back to fill up the space left by the boat is 1 foot per second. The velocity of the current along the surface of the boat will then be $(3' + 1' =)$ 4 feet per second, and against the surface of the channel 1 foot per second. The resistances *from friction* would then be represented by $(4^2 \times 30) = 480 + (1^2 \times 78 = 78) = 558$.

But suppose, what would probably be approximately true, that the velocity under the bottom of the boat was 4 feet per second, and that on each side $(\overline{300 \times 1} - 20 \times 4 \div (300 - 20) =)$ 0.785 feet per second. The friction against the bottom of the boat is then $(4 + 3)^2 \times 20 = 980$, and against the sides $(0.785 + 3)^2 \times \overline{2 \times 5} =)$ 143, and the friction against the part of the bottom under the boat is $4^2 \times 20 = 320$, and against the rest of the bottom and the sides is $(0.78^2 \times \overline{78 - 20} =)$ 35. The aggregate of all these is 1 478, being 165 per cent. more than it would be if the counterflow in all parts of the channel had the same velocity.

Judging from my own early experience, and especially from experiment, in towing heavy barges in a canal by locomotive on a railroad on the bank, I think the difference is greater than I have stated. I am sorry I did not preserve the numerical results. When possible, we deepened the canal, so as to give two feet instead of one under the boats, and with very great advantage. One foot area of water section under the boat, was of more value than several feet anywhere else.

In making a single track ship canal, say for ships of 26 feet draft, the parts of it in which ships are not to pass each other, should not, as commonly proposed, be 70 or 80 feet wide at bottom and only 28 feet deep, but should, when practicable, have nearly as much water under the keel as on each side of the bilge. Suppose a ship has 45 feet beam and 26 feet draft, she would probably meet with fifty per cent. more resistance in a canal 160 feet wide on the surface and 28 feet deep with slopes of $1\frac{1}{2}$ to 1, than if the canal were 148 feet wide on the surface and 34 feet deep; the area of the water prism being just about the same, and the area of the excavation, if in a deep cut, very much less. With the deeper water the ship steers so much better that she is much less likely to graze the banks though nearer to them.

Of course there are cases where this cannot be done, as over culverts, and others where it would increase the risks, as on high embankments. But because the best section cannot be got all the way, it is no reason why it should not be wherever possible.

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CXCVIII.

(Vol. IX.—July, 1880.)

NOTES ON THE SOUTH PASS JETTIES.

By MAX E. SCHMIDT, Member of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, MAY 25TH, 1880.

WITH REMARKS

By JAMES B. EADS, Member of the Society.

At the request of Mr. E. L. Corthell, Resident Engineer, and as an addendum to the paper of the writer of last year,* the following brief notes are submitted relating to the maintenance of the channel at the South Pass Jetties, and the general condition of the works.

At the head of the passes the 30-feet channel is now 450 feet wide, with a least depth of 30.1 feet. The improvement during the last year has been constant and more marked than at any period heretofore.

At the Jetties proper the channel has again improved in depth and width. There has not been a single day in the last five months on which the 30-feet channel has been found deficient, and during that time the dredge boat *Bayley* has been in service only 11½ days, when work was required near the sea ends of the Jetties, where slight fluctuations in the bottom, nominally closing the 30-feet channel must be expected

* Paper CLXXXIII. The South Pass Jetties. Max E. Schmidt. Vol. VIII., Page 189. August, 1879.

to take place, owing to the action of the waves and the effect of storms upon the mouth. But the consolidating works now in progress at the ends of the jetties once completed, there will be a permanent central depth of 30 feet and more, which will be wholly maintained by the action of the current, and require no dredging.

No examination has been made of the Gulf bottom immediately seaward of the Jetties since December, 1879, when a comparison with the survey of 1876 showed an average scour of 770 087 cubic yards, amounting in total to an average increase of depth of 1.22 feet. Since 1875 the increase in depth over an area almost identical with the one just named, has been one foot and one-tenth.

The construction of the concrete capping on the East Jetty is nearly finished, including the parapet which crowns the blocks.

The concrete work will ultimately extend over a distance of 5 159 lineal feet, commencing at a point 6 500 feet from the eastern Lands-end and terminating at the sea end.

The net amounts of material used in the construction of the Jetties are as follows :

13 000 000 feet B. M. of lumber.
600 000 cubic yards of willows.
100 000 " " of stone.
6 881.47 cubic yards of concrete for blocks and parapet.
375 000 feet B. M. of palmetto logs.

A complete history of the entire works is now being prepared by Mr. Corthell which will give all facts of interest to the profession and fully and freely discuss all questions connected with the works.

James B. Eads : I have but little to add of interest to what is contained in the statement just read. The statement is substantially correct.

I may remark that the depth which is given at the head of the pass, 30 feet and one-tenth, is measured on the plane of low water of the river. The average or mean flood tide is the plane which is referred to for all measurements of depth; but at the head of the pass that plane is established at the average flood tide of low water of the river. It makes a difference of two to three feet in depth. We have at this time about two feet depth additional to that which is reported; that is, through the head of the pass, where we had a shoal of 14 feet, and the removal of which shoal constituted the most important problem that

had to be solved, we have now 32 feet. The channel has been deficient occasionally at the sea end of the Jetties to such an extent as to require a few hours' use during the day of the dredge boat *Bayley* to remove it. It is caused by the fluctuation of the winds and waves. The volume of water which goes through the pass is capable of maintaining a certain section; if that section becomes too flat the 30 feet channel is likely to fail. We have to maintain a certain width of 26 feet water. That width must be 200 feet, and through the centre of that there must be 30 feet. We sometimes have too much 26 feet water, it gets too wide, and then the 30 feet channel shallows up a little near the ends. The inspecting officer has no discretion in the premises; and if he reports either one of the dimensions deficient, the payment stops, and only commences again when the channel is restored. The channel has, I believe, 32 or 33 feet as the least depth throughout the whole two and one-fourth miles of Jetty channel, with the exception of, probably, 300 or 400 feet near the sea end of the Jetties. That part of the Jetties is not yet entirely completed. We are consolidating the east Jetty. The west Jetty is finished, and those consolidated works are required to be extended probably 150 feet.

There is a very large amount of water round the end of the consolidated works, extended as far as they have been, and as they are extended to the end the part that is likely to fail being above that or immediately abreast of it, that will be corrected, and we will have, I think, 32 or 33 feet depth as the least depth throughout the channel in the course of two years. The channel is slowly enlarging; it is enlarging more slowly now under the action of the current than it has hitherto; as the equilibrium of forces is gradually restored it is restored more slowly; and that will result in a channel I think, at least 32 feet as the least depth throughout the work.

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CXCIX.

Vol. IX—August, 1880.

SHIP CANAL LOCKS CALCULATED FOR OPERATION BY STEAM.

By ASHBEL WELCH, Member of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, MAY 25, 1880.

So few canals have been built, and so many of those already built have been abandoned, during the last thirty or forty years, that very few engineers have considered them at all worthy of their attention. The few that have studied their construction and operation, have seldom published the results of their study, for nobody was sufficiently interested to read anything on the subject.

Recently, however, the project now seriously entertained, and which may sooner or later be executed, of making a canal across the great American Isthmus, has awakened a deep interest in this long neglected but now important subject.

I consider it due from the older engineers who have had experience in it, and have kept up their interest in it, to give the results to their professional brothers.

The great advantages of railroads over canals of ordinary dimensions, except to make short connections between existing water routes or harbors, or in some very exceptional circumstances, will doubtless continue in the future, as in the past, to prevent their construction. But short ship canals connecting ocean routes, many thousands of miles in length, will be sure to be built hereafter. The great difficulty in the way of making such canals, is the locks, or the enormously expensive, dangerous and every way objectionable deep cuts made to avoid them. A proposition to obviate, or lessen the objections to such locks is therefore now opportune.

In order to a full view of this subject, it will be necessary to repeat some things I have said on former occasions at the meetings of this Society in New York. But as some details now proposed vary from those then contemplated, some dimensions and calculations will vary from those then presented.

In ordinary locks of former times, the strength of a man was sufficient to open and shut the gates, valves and wickets. The team of horses or mules could haul the boats in and out. When steamers came they could move themselves in and out. If they glanced against the walls, their weight was not such as to make the collision very injurious.

But in locks large enough for ships, all this is different. Men cannot open and shut the main gates, or the feeding and discharging gates in any reasonable time. Quadruped power cannot haul a ship in or out. Capstans and windlasses worked by men can haul them only slowly and laboriously. Lines light enough to be handled by men will not hold a ship safely. Steam on board acting against unstable water, is not certain enough, or quick enough, or controllable enough, to be trusted. A slight collision against the walls might indent, or even break the skin of a ship.

In my younger days I had charge of the Delaware and Raritan Canal, where the locks and vessels were so large that the working of the one by

hand, and hauling of the other by animals, was always a source of delay, and sometimes of accident. Lock tenders, vessel's crews, and team drivers, commonly inexpert at best, often failed to act in concert, especially in the night and in the storm. At a very early period I contemplated the application of a power to operate the locks and haul the vessels, which had become a well matured, well trained and obedient servant to the human will, the steam engine ; not afloat, but stationary on the wall of the lock. A dozen years ago, in 1868, the canal having reached the limits of its locking capacity (though I had then no special charge of the canal, more than all the other works between New York and Philadelphia), I applied the steam power at the locks, thirteen in number, and at once increased their capacity, and, therefore, that of the canal, fifty per cent. Accidents, not infrequent before, are, so far as I know, unheard of since. It is still in operation, and its success is complete. The apparatus is so safe and so strong, that I never heard of anything getting out of order or breaking during the dozen years it has been in use.

The engine has two cylinders, each 6″x12″, turning a drum 3 ft. in diameter, which moves an inch wire rope 2 200 ft. long, passing around sheaves above and below the lock, and passing over rollers along the face of the lock. The vessels are attached to this by short lines. The rope moves half as fast as the piston. The greatest strain ever put on the rope is rather under 6 000 pounds. The weight of the two boats, hauled in together, sometimes reaches 2 000 000 pounds. The engine also opens and shuts the gates, and works the valves by which the lock is filled. It also, in one case, turns a swinging bridge near the lock, on a much travelled road in a city, in a quarter of the time it previously took to turn it by hand.* I carefully calculated all the powers, resistances, strains, and strength beforehand. Though much thought was expended upon it, the whole apparatus when done is "ridiculously simple."

The full advantage of steam cannot be availed of in working existing locks, or locks made after old models, for they are not calculated for it. We must then make bold and radical changes, and adopt new arrangements by which that power can be used to the best advantage.

My present object is to point out how a ship canal lock of the most

*The engine and machinery were made by Mr. William Cowin, at the Lambertville Iron Works, the details arranged by Mr. William Johnson, the mechanical expert at those works. The ropes were made and advice given as to their strength and management, by Mr. John A. Roebling.

extreme dimensions, and of 30 feet lift, can be made, into and out of which ships of the largest size can be hauled quickly, and in which they can be held and handled safely, and all the operations of the lock performed surely and rapidly by a steam engine on the wall.

This mighty agent in its present matured state, so powerful, so controllable, so instantaneously, and so exactly obedient to human command, can with suitable appliances, which I propose to point out, be made to perform all the haulings and holdings of the ships, and all the openings and shuttings of the gates and valves, safely, certainly and quickly.

Water power cannot so well be applied directly, for its changes are not quick enough, but it may be applied through hydraulic engines with great advantage.

It appears from the advice they have given, that some of the most eminent engineers of the world have not thought of this plan, or at any rate, have not thought it out, and that for want of considering what can be done, and knowing what has been successfully done already, they, as well as most persons interested in ship navigation, including naval officers, consider locks for ship canals absolutely inadmissible. I repeat what I have already said on more than one occasion, that if locks for ships could be operated only in the old way, I would no more build one than undertake to row the *Great Eastern* across the Atlantic by human hands. Knowing only the old way, those engineers were right in advising a level canal from the Atlantic to the Pacific, notwithstanding its enormous cost, its unavoidable narrowness involving great delay and risk, its exposure to floods only imperfectly diverted, and all the dangers and expenses almost always incident to deep cuts.* Some of those risks I adverted to more fully on a former occasion.

I do not claim that the precise plans and arrangements I propose are the best possible. I wish rather to present what is simple, and unmistakably practicable, than what may be really better, but the practicability of which is not so evident. An expert mechanic could, doubtless, improve upon some of the details of my machinery; if so, the argument in favor of the general plan is all the stronger. If the apparatus, as

*The Chesapeake and Delaware Canal has a deep cut about a mile long—I don't know the figures, but I suppose that first and last the maintenance of the canal through this cut has cost more than the maintenance and operation of all the locks on the canal. The "Gap Cut" on the Pennsylvania Railroad gave a great deal of trouble for years and cost a good dea of money.

presented, will answer the purpose well, much more will it when made more perfect.

The first thing to be done is to get out of the old grooves, and into sympathy with the age; to forget precedents established in other countries, under circumstances entirely different, when all was on a small scale, and before the arts now applicable had grown to maturity. Plans all right for the little canal of Languedoc, two centuries ago, are not good precedents for a ship-canal in America in 1880. When they talk of canals, eminent engineers seem to have forgotten, or rather not to have taken the time to apply the originality, skill and ingenuity that they have applied to everything else.

I am indebted for some of the ideas now to be presented to the experience of my old friend, Edwin A. Douglas, on the upper Lehigh. It was his good fortune to know little and care less about old rules and precedents.

Sketch No. 1, Plate XII., shows the general ground plan, on a small scale, of a lock 680 feet long, with chamber 600 feet by 80 feet, with a channel on one side to bring the water, which I shall call the inlet channel, and a channel on the other side to carry it away, which I shall call the outlet channel. Where it is possible the water should come into and go out of these channels not from the canal immediately above and below the lock, but from and to some expansions of the canal, or reservoirs outside of it, away from the lock, so as always to avoid any current near the lock. The prism of the canal should be enlarged and deepened immediately above and below the lock, so that vessels can be moved with the least resistance and most certainty. Racks should be used where the water is admitted into the reservoir, or inlet channel, to exclude floating wood or brush.

This plan contemplates two water ways at right angles to each other, one for the passage of vessels only, longitudinally through the lock, the other for the passage of water only, transversely to the axis of the lock, first through one wall to fill the chamber, then through the other wall to empty it.

This avoids the principal sources of expense in maintaining the lock itself, the wickets in the movable gates, and the collisions and rough contacts of vessels with gates caused by longitudinal currents produced by filling from one end, and emptying at the other. It also avoids the injury to vessels from collisions caused by those same currents. In filling

and emptying through the sides, the openings should be so spaced as to cause no longitudinal current in the chambers.

Where lock gates are opened and shut by human muscle, the temptation always exists to let on a little water, and let its pressure aid the operation. This brings the gates against the mitre sill with a slam, and if they do not come shut at the same moment, often twists, sometimes unships them. Where the gates are opened and shut by steam, without human effort, there is no temptation to do this. There is little else about a lock that ever needs repair.

I have calculated for a lock of these extreme dimensions, 600 feet by 80 feet chamber, and 30 feet lift, to show how easy it is, if you have plenty of water, to pass the largest ships safely and quickly; and though the cost of construction and operation are very great, they are very little in comparison with the amount saved by them.

Where there is not plenty of water, the lock should be narrower, and water-saving basins made as pointed out hereafter.

Floats, not solid walls or wharves, should form the approaches. Large ships should not be allowed to touch solid walls or the lock gates, and commonly not even the floats.

I have calculated for a lift of 30 feet. Probably that is as high as the ground will permit any lock to be made. I should not hesitate to go higher than that if the situation permitted.

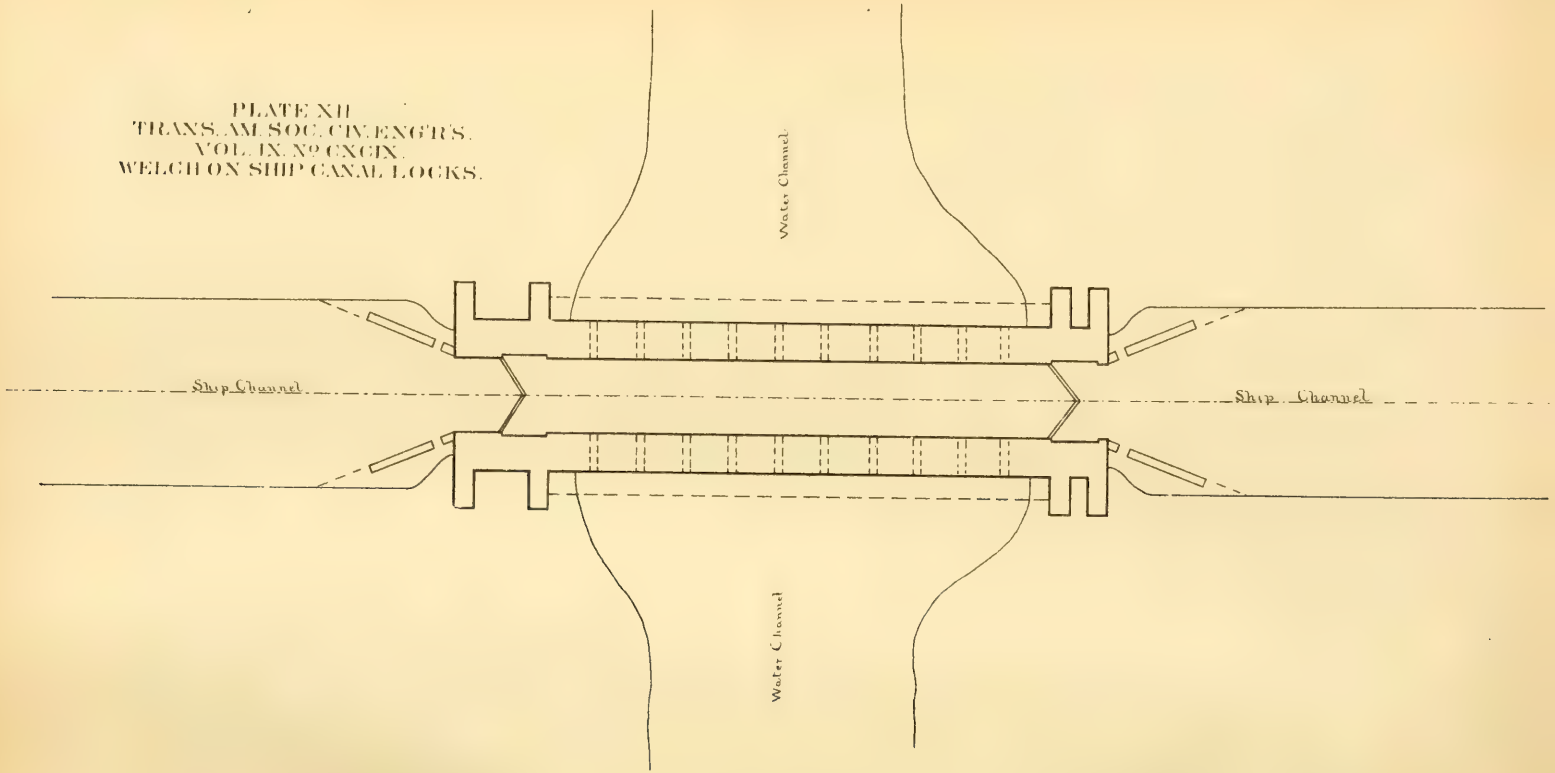
Where there is plenty of water, or where water-saving basins are used for the locks of large lift, there is no necessity for the traditional Procrustean rule of making the locks of uniform lift whether that fits the ground or not. Mr. Douglass, already mentioned, made locks of 33 feet lift, which worked easily, safely and well for a quarter of a century. They were emptied in two minutes. The higher the lift, the less the cost of construction and operation, and the less the detention, per foot lift.

In making a lock on the plan I propose, the one vital part requiring the most special care is the foundation platform. A lock foundation has two duties to perform; first, to distribute and sustain the weight without settling, or settling unequally; and, second, to hold the water *upon*, and not to allow any of it to get *under*, the platform.

On anything but sound, solid rock, an artificial foundation is, of course, necessary.

If the rock is suspected to be cavernous, it should be bored, and

PLATE XII
TRANS. AM. SOC. CIV. ENG'RS.
VOL. IX. Nº CXCIX.
WELCH ON SHIP CANAL LOCKS.



if small cavities are found, they may be filled with grout, the water rising through a second hole bored into each cavity. The holes should, of course, be carefully filled. If the rock is seamy, it should be taken out a foot or two deep, the seams cleaned out and grouted, and the whole surface covered with a stratum of concrete.

If the bottom is anything but rock, hard-pan, gravel, or clean sand, or some other incompressible soil, with the great weight required by this plan to be put upon it, it should be piled. Clay should not be trusted; it compresses unequally. The piling should not only be under the walls, but under the water-spaces as well, for in a ship-canal lock of 30 feet lift, the pressure on the bottom of the chamber will vary from nearly a ton on the square foot to double that pressure. The length and number of piles must depend on the circumstances of each case, and be governed by rules already well understood.

For such a lock the foundation platform should consist of, first, a stratum of the best concrete not less than 18 inches or two feet thick, and on it (and upon, not between the piles, if there are any, unless under the walls) long stiff hard wood timbers, flatted out of wind, smooth on the top, 18 inches deep, should be placed transversely covering the whole space under the walls and under the mitre sills, two-thirds or three-quarters of the space between the walls. The interstices between the timbers should be perfectly filled with concrete, or where too narrow to get it in, with grout. The timbers should break joints so as to have as far as possible the same effect as if they extended all the way across the foundation.

The covering on these timbers laid parallel to the axis of the lock, should be, under the walls, jointed timbers of hard wood 12 inches thick, and under the water spaces 4-inch carefully jointed white pine plank.

White (not yellow) pine is the best for this purpose of anything I know. It swells when wet, and remains swelled under water, so that it prevents leakage at the joints, while it is so compressible that the swelling can with proper care be prevented from bulging up the floor. When put in it should be as much as half seasoned, and in that case, wedged together very hard; if fully seasoned, not very hard. When laid, the concrete and timber should be covered with a little thin mortar to ensure a perfect contact between the floor plank timber and concrete, and freedom from any minute interstice which is liable to become a water channel. I have always found wood and cement together much safer to

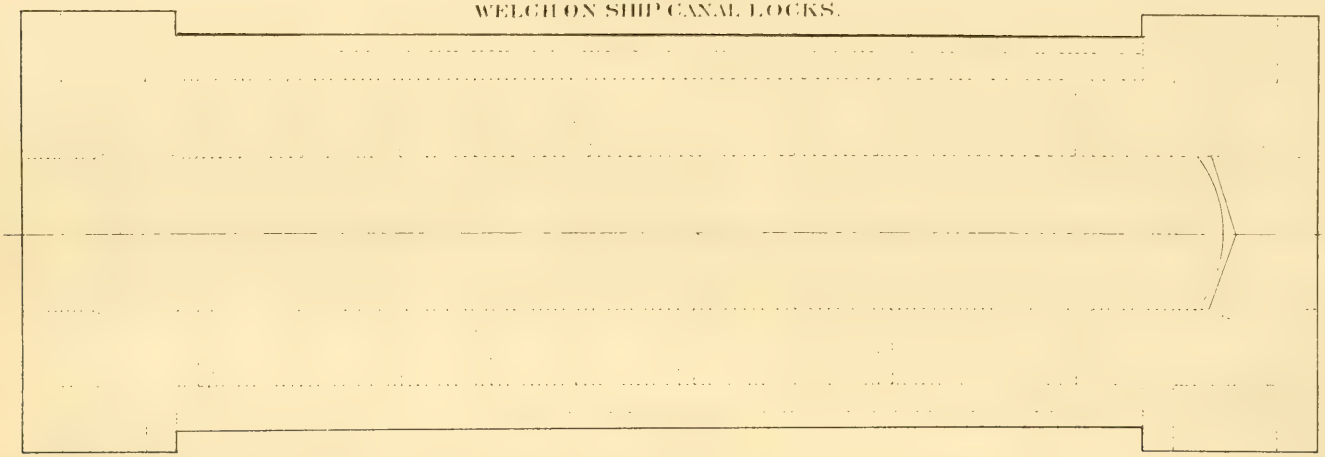
hold water than either separately. The cement stops an open joint, crack, worm-hole, or knot-hole in the wood; the wood does not allow the water to reach a crack or defect in the concrete. The cement under even very thin plank saves it from wearing in the joints by a strong current upon it. The union between cement mortar or grout and timber is very perfect.

Whether spikes are used or not, the floor should be tree-nailed to the foundation timbers. The tree-nails should be of white oak or other tough, hard wood, turned, not shaped with the axe, but turned, 20 inches long, $1\frac{5}{8}$ diameter, following an inch and three-quarter angle, the 4 inches through the plank tapered so as to be a quarter of an inch larger at the outer end. This prevents the tree-nails from drawing through the plank; there is no danger of their drawing out of the timber. I used this plan for many years. In former days many thought square tree-nails in soft wood held best, but it was a mistake. The grain of wood should be compressed, but never broken or crushed; that destroys its holding power.* Besides, there is danger of open spaces along the flat side, in which the water whirls and cuts. The object of tree-nails which offer so much more surface than spikes or bolts against the fiber of the wood to resist the sliding of one piece of timber or plank over another, is to prevent the floor planks from crawling, and thus breaking loose from the concrete underneath, For a similar reason I have always used tree-nails in the bracing of timber trestles for railroads. I am thus minute, because in this matter few engineers have had experience, and the foundation platform is the all important, and the one difficult thing to execute. This is one of the cases where success depends very much on practical details.

If the material under the concrete is clay or anything softer, I would cover it with a foot or two of gravel under the concrete. Otherwise if a film of water should get to running under the concrete and in time wear off some of the clay, it would leave a cavity which might increase and in time become dangerous. But with the gravel, which drops into and fills up the minute channel immediately, its enlargement is prevented, and the film of water is either stopped or runs harmless over the gravel. Most of the failures I have known in anything from the action of water, have originated in this operation on clay. A driblet of water following

* For this reason ragged spikes, as I have found by experiment, do not, in many cases, hold as well as plain.

PLATE XIII.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. IX. No. CXCIX
WELCH ON SHIP CANAL LOCKS.



a rootlet gradually forms a channel, the clay instead of falling together like gravel, arches over, a water course is formed and disaster follows.

I suppose European engineers would reject my wooden platform with scorn. If they had our American experience they certainly would not. The stratum of concrete alone is not safe, it may crack ; the plank platform alone is much safer, but in connection with the concrete as near absolutely certain as any man-made structure can be. I would as soon think of dispensing with wooden cross-ties for a railroad, and going back to stone blocks, as dispensing with the timber platform.

If the water is brackish it may be necessary to cover the whole floor with a stratum of cement and coarse sand a few inches thick to protect it from the teredo.

Under the outside of the platform along both sides and across the head and foot, under the mitre sills, I would build, if not on rock, a continuous wall of concrete or grouted masonry, 4 feet to 6 feet thick, and 6 feet to 12 feet deep, or where the soil is not water-tight even 20 feet deep, according to circumstances, with 4-inch sheet pilings on the side from which water may come, the contact of wood and wall being made perfect by mortar and grout. Other stop-water walls and sheet-pilings may be built, especially longitudinally under each main wall, where there is any possible danger.

The continuity of the floor should be absolutely unbroken over the whole space. This excludes stone mitre sills, which I would not use in any case. Wood or iron are much better. In building on rock, I would excavate three or four feet extra depth, under the swing of the main gates across the chamber between the lower recesses, so as to enable the water to pass under as well as around the gates from one side to the other, and thus make them swing more easily. But I would not make a break or offset or step in the floor even for this purpose.

The entire sufficiency of any one of the foregoing means of safety should not prevent the adoption of all the others. In this case we want the security derived from several concurrent certainties. I have gone much into detail in this, because it is the one vital thing. The platform once secure, there is no difficulty about anything else.

If it is suspected that the timber enclosed in cement may suffer from dry-rot, it should be previously steam seasoned and treated with creosote or some other preservative.

The form and dimensions of the platform are shown in sketch No. 2, Plate XIII.

Sketch No. 3, Plate XIV., is a section tranversely through the middle of the lock, showing the platform, the stop-water walls under it, and the walls upon it.

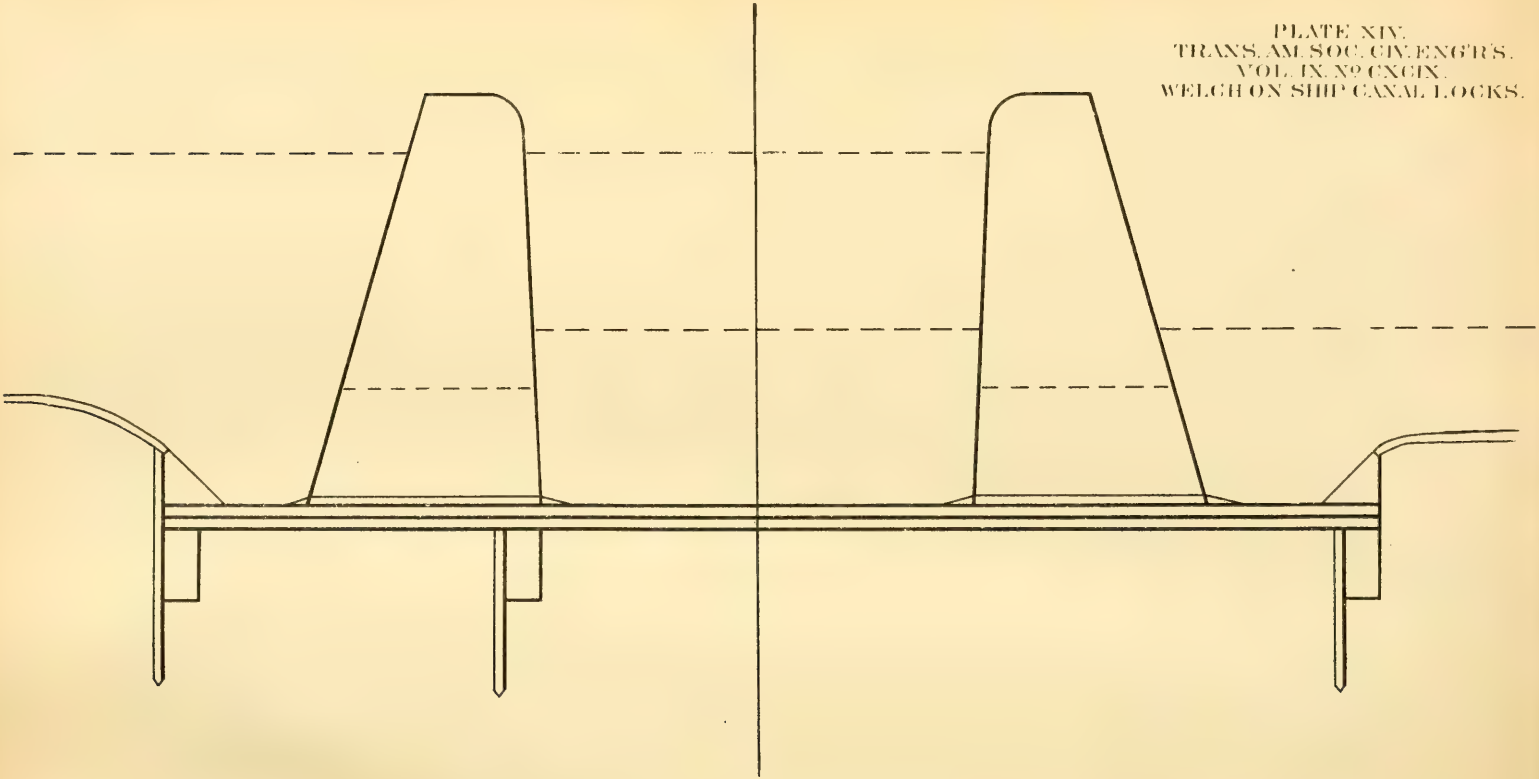
Beginning on the left side we have first the sustaining wall of the outside of the inlet channel, 10 feet thick at bottom, measured on the platform, 10 feet high on the back, supporting a slope wall laid in cement, resting on an inclined stratum of gravel or concrete. This sustaining wall should be perfectly water tight, and backed up by perfectly water-tight puddling. The special risks to be most carefully guarded against when this plan is adopted, is the risk of the water getting around the edge of the platform, and so under it. Besides the stop-water wall under the edge of the platform, assurance may be made doubly sure by building another one under the main-wall. This sketch supposes the water to come into the inlet channel at right angles to, not alongside of, the lock from the head. The bottom of the inlet channel should in this case be 15 feet wide. If the water comes in from the head of the lock it should be 20 feet wide.

The main walls, as I shall call them, or side walls of the chamber are proposed to be 40 feet thick at bottom and 20 feet at top-water line, to batter 2½ feet (half an inch to the foot) on the face, and 17½ feet on the back. The water when the lock is technically empty being 30 feet deep, and the lift 30 feet, the height to top-water is 60 feet. The thickness is intentionally excessive (see note A). At the bottom next the face and at the angles and shoulders of the recesses and openings, the wall should be of large, dressed stone, all the rest good rubble, grouted or otherwise carefully insured against interstices. An interstice communicating with the high level counteracts half of the weight of the wall over it. As the best engineering is that which answers the purpose well at least cost, I would use no cut stone. One dollar spent in getting better cement, does more good than ten spent in dressing stone. Good cement with clean sand filling the whole space between the stones, makes the whole wall one great monolith.

Each main wall is pierced* with ten openings, each 8 feet wide and 12.5 feet high to the spring of the arches of the semi-cylindrical heads, each opening being 100 square feet at the throat. The outer end of these openings should be fan-tailed. Though large ships and steamers should

* Mr. Douglass emptied his locks through the side walls more than forty years ago.

PLATE XIV.
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. IX. Nº CXCIX.
WELCH ON SHIP CANAL LOCKS.



not be allowed to touch the wall, small vessels may, and with a view to their protection, I would cover the face of the wall with 4 or 6-inch plank of soft elastic timber. This, under the surface of the upper level, will last indefinitely. I have found this cheaper to maintain than cut faced ashlar —and far better for the vessels. If I had a lock already built with a cut stone face, and if it were wide enough, I would cover it over with plank. The finish of the top of the wall must be adapted to the machinery to be put upon it.

The width of the chamber is 75 feet on the floor, which makes the width at top-water when full 80 feet.

The bottom of the outlet channel is 20 feet wide, and the sustaining wall on that side 10 feet.

This makes the whole width of the platform $(10+15+40+75+40+20+10=)$ 210 feet.

Sketch No. 4, Plate XV., is a longitudinal section along the axis of the lock at the upper end, showing a section of the breast wall, upper mitre sill, head wall and iron tube for passing the ropes from the engine to transmit the power to the other side of the lock, and the guard-gate to shut the water out of the lock when necessary. The tube is embedded in the masonry to protect it from accident. A space of several feet is left below the swing of the upper gates to enable the water to pass under as well as around them, and so diminish the resistance of the water to their rapid swinging.

The inlet gates, to admit the water into the lock, should be made to hoist and not revolve so that the current created shall strike under, not against the ship then in the lock, and so that it shall not send the current into the lock obliquely. The opening being 8×12.5 feet, the gates should be about $9.5' \times 12.63'$, making their outer surface 120 square feet. I would make the gate of 12-inch timber; battened on the lower side so that the grain of the battens should slide with the grain of the wooden posts against which the gates set. If the gates are of iron still the sliding parts should be wood. The power to move the gates should be in the same plane as the sliding surfaces. As the water presses on the top of the gate the bottom should be bevelled nearly to an edge at the lower side, so that the water shall also press up on the bottom. The stem and battens of these wooden gates should be fastened by $2\frac{1}{2}$-inch turned tree-nails, as well as by screw-bolts, so as to offer as much surface as possible to prevent the grain of the wood from crushing or com-

pressing by the shearing motion. The power to move these gates may be transmitted from the engine by hydraulic apparatus, or by ropes.

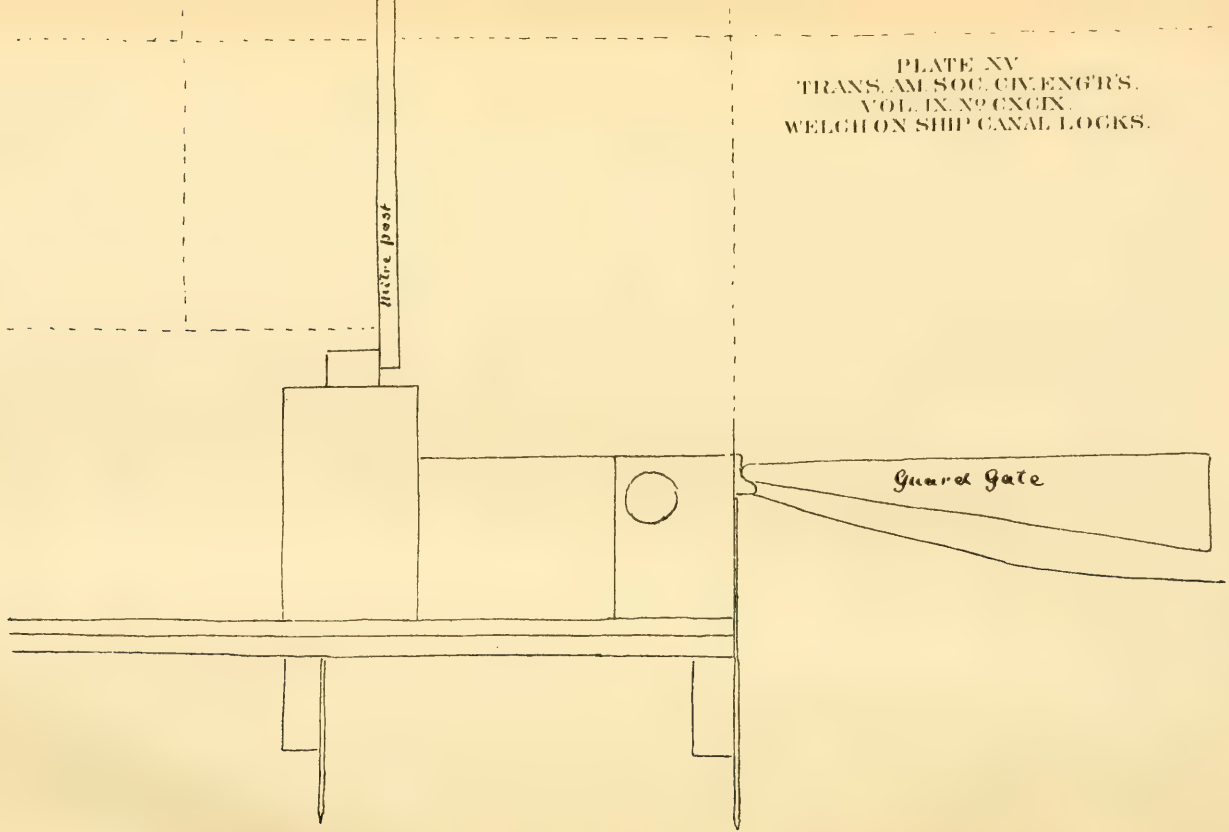
I have been accustomed to work gates larger than these, though not under so great head, by screws worked by hand. I propose for these gates, screws of 2-inch pitch, fixed to the stems of the gate (their axis being, of course, in the same plane with the sliding surfaces of the gate), passing vertically through thick nuts resting on the wall. Either the screw or nut may be made to revolve ; whichever revolves will be turned by ropes from the engine around vertical drums. A dry well may be made for the screw, the stem passing through a stuffing box.

The area of the orifice is 100 square feet, but the area of pressure against the gate is 120 square feet under 30 feet head. This makes a pressure of $(120 \times 30 \times 62.5 =)$ 225 000 pounds. If the wood of the sliding surface is thoroughly saturated with tallow, the effect of which lasts a long time, the friction will not exceed one-eighth of the pressure. One-eighth of 225 000 is 28 125 pounds, the power required to overcome the friction. Add to this the weight of the screw and stem, and that of the gate less its buoyancy, say 3 875, bringing required power up to 32 000. Add for friction of the screw, &c., 50 per cent., bringing the requirement of power to raise the gate up to 48 000 pounds. To raise the gate one foot in three seconds the expenditure of power is therefore 16 000 foot pounds per second for each of the ten gates. To raise it one foot requires six revolutions of the screw or nut. If the drum is 30 inches in diameter or 7.5 feet circumference, the rope moves $6 \times 7.5' = 45'$ to raise one foot, and if this is in 3 seconds the rope moves 15 feet per second. The strain upon the rope is $\frac{48\,000}{45} = 1\,066.66$ pounds. For this a half-inch rope is sufficient. Of course there must be two ropes from the drum to the engine—one to raise and one to lower. There should not be one endless rope, as it may slip, and render the action uncertain, but separate ropes each attached to the drum. The height of the drum to raise the gate 12.5 feet must be $(12.5 \times 6 \times 0.55 =)$ 41.25 inches, say, 3.5 feet. The whole movement of the rope is about 560 feet. If the above motion of the screw is too rapid the pitch and the size of the rope may be increased.

The whole amount of power required to raise these gates simultaneously one foot in three seconds, when the resistance is greater is $(16\,000 \times 10 =)$ 160 000 foot pounds per second.

Such gates commonly require no repairs for years.

PLATE XV
TRANS. AM. SOC. CIV. ENG'RS.
VOL. IX. Nº CXCIX.
WELCH ON SHIP CANAL LOCKS.



by hauling and handling the ships by the cable worked by steam. Costly maintenance of wickets is avoided by having none in any of the gates. In fact, with the plan now proposed, all causes of damage to the lock itself are avoided.

The weight of water 30 feet deep in the sector through which the main gate swings, is about 2 000 000 pounds. If the gate is opened or shut in 40 seconds, then, to overcome the inertia of this water and send it round to the opposite side of the gate, and create all the other unavoidable currents, and overcome all friction, I estimate to require 80 000 foot pounds, or 2 000 per second. If the gate is moved by a fan-shaped lever 20 feet long, the strain upon the rope is 4 000 pounds, and its movement is about half a foot per second. An inch rope may be used to bring the power from the engine, or the inch rope may pass around a drum 3 feet in diameter, and a half-inch rope around a 12 feet drum, on the same shaft, may bring the power from the engine.

To overcome the inertia of a ship weighing 40 000 000 pounds, and give it a velocity of 3 feet per second in 60 seconds (neglecting at present the resistance of the water) requires (32 : 40 000 000 : : $\frac{3}{60}$:) 62 500 pounds strain on the hauling cable. At the close of the 60 seconds the power expended is 187 500 foot pounds per second, though when 3 feet velocity is established it will take less than 100 000 foot pounds per second to maintain it. To transmit this power requires a rope 3 inches diameter, and the drum around which it passes must be 9 feet in diameter.

The water immediately above and below the locks should be wide and deep, so as to give as little resistance as possible to the motion of the ship. On the canal of which I once had charge I deepened 2 feet or 3 feet above and below the locks.

The hauling cable should pass from the drum that moves it up and down parallel to the lock to sheaves a little over 2 500 feet apart, making the whole length a little over 5 000 feet. About half of this length, along the face of the lock wall, so located as never to reach the drum, and to which part of the rope the ships are to be fastened, should be enlarged to 5 or 6 inches diameter, or rather to a flat rope $2\frac{1}{2} \times 12$ inches, so as to have, besides the strength to haul, the strength to stop a ship by the application of a brake. The sheaves around which this enlarged part passes should be 20 feet diameter, or more. This enlarged part passes through brakes formed with short endless bands passing around the brake blocks over and under the cable, the bands being carried along by

the cable so as not to chafe it, to be operated by ropes from the engine. Probably their application to stop a ship may not be required once a year, but they should be used constantly to hold the ship still. This part of the cable will bear a strain of 200 000 pounds, and this is sufficient to stop a ship weighing 40 000 000 pounds and going 5 feet per second in 30 seconds, or if the velocity of the ship is 3 feet per second in less than 20 seconds, and in less than 30 feet.

The ship may be connected with the hauling cable by two short hemp cables 5 inches diameter, one leading forward from the ship's bow, the other aft from her quarter. These should be handled and passed over the ship's side by light shears or derrick booms. They should be hooked to securely-fastened cables on board, either belonging to the ship or furnished to it as it enters the canal and given up as it leaves.

As the engine does only one thing at a time, the greatest amount of work required of it is that which will perform the heaviest single operation, which is moving the hauling cable three feet per second, requiring 187 500 foot pounds per second. The next greatest is to raise the inlet gates, requiring 160 000 foot pounds per second.

I propose an engine of two cylinders, each 24×42 inches, with 50 pounds effective mean pressure on the pistons throughout their stroke, the pistons, when doing full work, moving 7 feet per second, giving to the engine one revolution per second. The power developed per second is $(2 \times 50 \times 7 \times 24 \times 24 \times .7854 =)$ 316 673 foot pounds. If 40 per cent. is lost by friction of the engine and in the transmission by the ropes, we have left available at the points where the power is to act about 190 000 foot pounds per second.

The hauling cable drum having 9 feet diameter, or 27 feet circumference must revolve once in 9 seconds to give the rope and the ship a velocity of 3 feet per second, so the engine must make 9 revolutions while this drum makes one ; and the ship moves 3 feet, while the piston moves 7 feet. I would have an intermediate shaft worked by the pinion on the crank shaft, making one-third as many revolutions as the engine, which I will call the working shaft, and which always moves when the engine moves. This drives the cable drum shaft, the connections being made and unmade by a suitable clutch. The motion of the cable is reversed by reversing the engine.

The two ends of the cable being attached to opposite ends of the

drum, the two parts alternately occupy the intermediate space. The drum must then be about 22 feet long.

It will not do in this case to use endless ropes and rely upon friction.

The drums which move the ropes that work the inlet gates may be loose on a shaft of their own and worked from the working shaft, being thrown in or out of gear and their motions reversed by V-shaped friction clutches. If these drums are 5 feet diameter they must make one revolution per second (3 times as many as the working shaft), and the length of each drum to hold the two ropes (each moving about 560 feet) is $\left(\frac{560}{15} \times 0.55 = \right)$ a little over 20 inches. The object of making these drums so large is to avoid excessive length of the shaft, around, but not fast to, which they revolve. Each of the ten drums is connected with the working shaft by separate clutches, but, as they will nearly always work together, the separate levers can all, or any part of them, be moved by one common handle.

Breast lines, to haul or hold the ship in the right place, should be operated by the engine, and moved along by it as the ship moves. There are several ways of doing this. I will tax your patience by describing only one.

The breast lines may be hauled and moved along as the vessel moves by apparatus similar to the travelling cranes at Crewe and at Altoona, used for lifting and handling locomotives. This apparatus may move lengthwise of the lock on a railway in a longitudinal depression or continuous pit 2 feet deep on the top of the side wall, and for 800 feet or 1 000 feet above and below the lock on piers or trestles well tied back to the land. These railways need not be straight nor parallel to the centre line of the lock, though they should be as nearly so as practicable. The pen and ink sketch, No. 5, Plate XVI., shows the position of some of the more important parts. The rails in the bottom of the pit are represented by *rr*. The wheels on the plan (not shown in the end view) are represented by *WW*. To avoid multiplying lines the frame is not shown, except the bottom plate in the end view. The very heavy horizontal strain upon the frame, caused by hauling the breast lines, comes against a rail, *T*, set with its base against the shoulder of the pit, bearing against which the two double-flanged horizontal wheels, *HH*, sustain the sideways pressure. To prevent the leverage of the strain upon the breast line from causing the apparatus to revolve around *T*, the other side of it is

PLATE XVI
TRANS. AM. SOC. CIV. ENGRS.
VOL. IX, NO. CXCIX.
WEIGHTON SHIP CANAL LOCKS.

kept from rising by a roller, *C*, under a flange, *d*, fastened to the other shoulder of the pit.

The endless ropes that bring the power to operate the apparatus may be less than an inch in diameter, of cotton or linen, passing around sheaves at each end of the railway travelled over, and should move with great velocity. The part of the power rope moving towards the engine may pass around the loose pulley, *L*, which, when necessary, may be made fast by a friction clutch so as to turn the pinion, *P*, driving the spur wheel, *S*, on the same axle as the pinion, P^1, driving the spur wheel, S^1, on the same axle as the grooved wheel, *G*, which hauls the breast line, *B*. The stray end of this line may be taken up on a reel, *R*, to which power enough should be applied by hand or by a belt to keep the line taut, so as not to slip in the groove. Of course the part of the line that reaches the grooves should be of some pliable material, not wire. The part of the power line moving from the engine may pass around a loose pulley, L^1, which may be made fast by friction clutch, and made to move the apparatus over the railway, a bevel pinion driving a bevel wheel on the flange side of the wheel *W*.

To perform all the operations other than hauling the ships and raising the inlet gates the motion of the engine may be very slow, and the steam in the cylinder at very low pressure. The drums for all these operations may work loose on a shaft on the side of the working-shaft opposite to the drums that work the inlet gates, and be connected by V clutches. The apparatus is so simple, and so like that already described, that further description is unnecessary.

Where the changes in temperature are great, tightening pulleys may become necessary, though I have always found the weight of the ropes themselves sufficient.

The engine should be near the head of the lock, as the tube through which the power is carried to the other side is at the head. It should be on the side where the most power is used; that is, the side where the hauling cable and the inlet gates are.

The engine and all the clutches should be handled by one expert, standing on an elevated, sheltered, glass-sided observatory, projecting out over the face of the lock wall, with the levers and handles and connecting links and hooks all within his reach without changing his position or even looking around. Just this has been successfully done for a dozen years, though not on so large a scale.

The whole number of levers in ordinary use will be (throttle, reverse, cable drum clutch, brakes 4, main gates 4, inlet gates 10, outlet gates 10, breast lines 4 —) 35. But they may be so connected as to be commonly worked by 15 handles.

It may be well to have indicators or marks on the ropes to show when the operation is about to be completed.

Though the expert has so many things to do, and so many levers to handle, he is in no danger of becoming confused, for, with only one or two rare exceptions, only one operation is ever going on at a time.

In addition to these daily operations provision should be made, by suitable connections with the engine, to raise the guard gates at the heads of the lock and of the inlet channel, and, with shears or derricks, kept on hand, to lift out and replace the main gates, and the inlet and outlet gates, and to handle coffer dams, should they ever be required, and to pump out the water. One extra drum at the engine would answer all these purposes in succession.

It may be objected that with so much apparatus something is always liable to go wrong and interrupt the navigation. Apparatus not more simple, and working under disadvantage, because the locks were not calculated for it, has been in operation a dozen years, and, so far as I know, it never got out of order so as to cause an hour's delay. Multiplicity is not complicity. Bell wires or telegraph wires do not work badly because there are many of them.*

Hundreds of things are in constant use more complicated and more difficult to operate, in many of which failure would be more disastrous. The application of steam to operate locks is no longer an experiment.

I have all along intentionally overestimated the frictions and strains, and calculated for excessive power and strength.

I have supposed the power transmitted by ropes. A better way may be by hydraulic apparatus. Then water power, if it is to be had, could do the pumping; or if steam is used a much smaller engine would be sufficient. I have not undertaken to describe or decide upon the best plans, but to give plans that are practicable—to show that locks for the largest ships can be made, and safely and expeditiously operated, at a

* Many years ago I pumped the water from a wet excavation on one side of the Delaware by water power a thousand feet distant on the other side, carrying the power across the river by a rope supported on triangles made of saplings cut from the woods. Almost any one of the operations proposed is easier than that, and of much the same kind.

cost which, though great, and at a moderate delay, and without danger, is as nothing compared with the cost, danger and delay which has been proposed to be incurred to avoid them.

When water is scarce one or more water saving basins may be used. Each should have a surface eight or ten times as great as the lock chamber. The communications between them and the chamber may be by large pipes resting on the foundation platform, passing through the outlet or inlet channels, or both of them, the last instalment of discharge when emptying, and the first when filling, being through other openings in the wall into or from the space over the tops of those pipes.

The time required to pass the lock after the ship has come to, may be estimated as follows:

To hook on the hauling and breast lines	1	minute.
To give velocity of 3 feet per second in 135 feet	1.5	"
To move 540 feet at 3 feet per second	3	"
To stop in 135 feet	1.5	"
To shut the lower gates	1	"
To fill the lock safely (outside calculation)	6	"
To open the upper gates	1	"
To overcome the inertia and move 810 feet	5.5	"
	20.5	"

A ship going down could pass two or three minutes sooner, as the lock can safely be emptied in three or four minutes. The lock, with no vessel in it, can be filled or emptied in two minutes. A vessel going up should be held near the outlet side of the lock, going down near the inlet side.

I should estimate the whole detention of a large ship by a lock at something less than half an hour, of a smaller vessel or any steamer at considerably less.

The cost of such a lock in this country, under favorable circumstances, might be about as follows, where no piling is necessary:

Excavation of pit, say $900 \times 270 \times 40 \div 27 = 360\,000$, at 50c	$180 000
Pumping and bailing	20 000
Carried forward	$200 000

Brought forward		$200 000
Concrete foundation, $750 \times 210 \times 2 = 315\,000$ cu. ft., at 0.2	$63 000	
Timber platform, $750 \times 210 \times 2 = 315\,000$ cu. ft., at 0.6	189 000	
Stop-water walls under foundation, $3\,000 \times 5 \times 8 =$ 120 000 cu. ft., at 0.25	30 000	
		282 000
Main walls, $2 \times \frac{40+18}{2} \times 66 \times 750 = 2\,871\,000$ cu. ft., at 0.2	$574 000	
Cross walls, about $600 \times 60 \times 15 = 540\,000$ cu. ft., at 0.2	108 000	
Sustaining walls for channels, $10 \times 10 \times 500 =$ 50 000, at 0.2	10 000	
		692 000
Main gates and appurtenances, $4 \times 50 \times 60 \times 2 =$ 24 000 cu. ft., at 1.00	$24 000	
Inlet and outlet gates, screws, &c	25 000	
Ropes, sheaves, &c., &c	40 000	
Engine, boiler, and machinery about it	40 000	
		129 000
Unestimated items and contingencies		300 000
		$1 603 000

Where any such lock is likely to be built, it is likely to cost $2 000 000. When piling is required it may cost $200 000 more.

The annual cost of maintenance and operation of the lock may be as follows :

Repairs and renewals of engine, machinery, ropes, gates, &c., 12 per cent. on $130 000	$15 600	
Other possible repairs	4 400	
		$20 000
Coal for engine at full work only a very small part of the time may be 1 000 tons, $6.00	$6 000	
Superintendent, $2 000 ; 3 experts, $3 000 ; 3 machinists, $2 000 ; 3 firemen, $1 500 ; 30 other men, $12 000 ; extra man, $500	21 000	
Other expenses	3 000	
		30 000
Total being about the interest on $700 000, at 7 per. cent		$50 000

So we may say in round numbers that on the great American Isthmus, the cost of the lock, and the sum of which its maintenance and operation equal the interest, amount, all together, to $100 000 per foot lift, unless the lifts are low, which probably never need be.

Probably in almost every location where water is to be had, a better ship canal can be made with a few locks, and at far less cost, than a sea level canal. A small part of the money saved by the locks will in most cases make a broad and deep canal, where ships can go safely and rapidly, and pass each other anywhere, without delay ; instead of narrow, deep cuts, commonly dangerous and always expensive, where ships must move slowly, and commonly wait to pass each other.

The question must be decided in each case, whether the very large amount required for the construction and operation of a lock will save a larger amount in some other way, and whether the half hour's delay at each lock will save a greater delay in some other way.

The plan I have presented of the construction and operation of a ship-canal lock, is so simple, and its practicability so evident, your mental exclamations have probably so often been "why, of course," that I feel like apologizing for taking up your time in laying it before you. And yet, though so plain when once presented, eminent engineers have failed to see it.

Perhaps ship-canals may give way to ship railroads, as proposed by our honored Chairman. I have not gone into the railroad calculations, and have at present no opinion to express on that subject.

Note A.—*Stability of the Main Walls.*—The pressure tending to overturn the wall is $\left(30 \times \frac{30}{2} = \right)$ 450, with a leverage of $\left(30 \div \frac{30}{3} = \right)$ 40 feet ; the product is 18 000 ; and $(30 \times 30 =)$ 900, with a leverage of 15 feet, the product is 13 500. Add together these two products, and the whole tendency to overturn the wall around the bottom angle is represented by 31 500. The unit being the weight of a cubic foot of water.

The section of the wall may be divided into two triangles and a rectangle between them. The tendency to prevent overturning will be as follows : Front triangle $\left(2.5 \times \frac{60}{2} = \right)$ 75, with leverage of $\left(2.5 \times \frac{2}{3} = \right)$ 1.66, making the product 125 ; the rectangle is $(20 \times 60 =)$ 1 200, and the leverage $\left(2.5 + \frac{20}{2} = \right)$ 12.5, and the product is 15 000 ; the other triangle $\left(17.5 \times \frac{60}{2} = \right)$ 525, and the leverage $\left(2.5 + 20 + \frac{17.5}{3} = \right)$ 28.33,

the product is 14 875. The sum of these three products is 30 000. Call the specific gravity of the masonry 2, and we have 60 000. Add for the water over the third triangle $\left(17.5 \times \frac{60}{2}\right)$ 525, with leverage of $\left(2.5 + 20 + 17.5 \times \frac{2}{3} =\right)$ 34.16, which makes 17 937. Then the resistance to overturning is represented by 77 937 neglecting the weight of the water over the front triangle. This $\div$ 31 500 = 2.47 the factor of safety against overturning around the bottom angle. It can, therefore, only give way from disruption by the shearing effect of the pressure, and that is not possible if the wall is grouted, and the cement is good.

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INSTITUTED 1852.

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(Vol. IX.—August, 1880.)

DISCUSSION

ON

PAPER CLXXXVI.—THE USE OF STEEL FOR BRIDGES.*

By WILLIAM SELLERS, Member of the Society.

The paper which Mr. Cooper has contributed upon the use of Steel for Bridges, is so comprehensive and so justly conservative, that little remains but to emphasize his conclusions.

The position he takes as to the province of the engineer in determining the quality of the material he is to deal with, is eminently sound, and that it is so little observed is to be attributed, perhaps, to vicious, but long-established custom, for there are to-day very few specifications, whether for iron or steel structures, but in some way prescribe a process

* Paper CLXXXVI.—The Use of Steel for Bridges by Theodore Cooper, Member A. S. C. E., Vol. VIII., Page 263, October, 1879.

of manufacture; it is gratifying, therefore, to find an engineer who has had such large experience as Mr. Cooper in testing these metals, taking ground against a practice that stands in the way of all improvement in the process of manufacture. The engineer should deal only with the material as he finds it, and subject it to such tests as will determine its physical characteristics or such characteristics as qualify it for the structure in which he intends to use it; it becomes, therefore, a matter of the greatest moment to him what these tests shall be. In dealing with this portion of the subject, Mr. Cooper has omitted one important element, that is, capacity to bear fatigue, or perhaps he assumes that the ductility, as compared with the ultimate strength, will measure it, and it may be that this is so; but, with our present amount of knowledge upon this subject, I do not think that we can confidently affirm it; the proportion of ductility to ultimate strength is our most important factor, because of this we have the largest number of recorded experiments for comparison, but the capacity to withstand shocks or blows does not seem to bear any direct relation to this proportion.

There is little doubt but that steels of the higher carbonization withstand better than those of low, the kind of shock to which piston rods and crank pins are subjected, but this is not the kind of shock to which the steel in bridge structures is subjected in use, or that may be thrown upon it by accident; the safety of the one is assured by its capacity to withstand heavy strains without bending, that of the other by its capacity to withstand heavy blows under which it must bend without breaking; the capacity, therefore, to withstand such blows is one of the characteristics which the engineer's tests should determine; and the drop test with bending blows only, and reversing the piece after each blow until broken, should not be omitted until at least, a sufficient number of tests have been recorded to establish the fact, if it be a fact, that the capacity to bear fatigue has a definite relation to the proportion which the ductility bears to the ultimate strength.

The very sufficient reasons that the author has given for desiring the tests for ductility made upon the same form and size of specimens are equally applicable to the drop bending tests.

They should be made upon the same size of specimen with the same distance between the points of support, and with the same weight falling from the same height; perhaps no one is better qualified than the author to determine what these details should be, indeed it is quite probable

that this very kind of test is the one to which he alludes, when he speaks of the desirability of testing all steels by impact or falling weight, but from the context it is uncertain whether he proposes to test to destruction by an extremely heavy blow or by a number of blows, each heavy enough to produce a decided bend; for the purpose of comparison, however, it is important that the character of this test should be defined in all its details. I quite agree with Mr. Cooper in affirming "the import-"ance and necessity of requiring a ductile metal regardless of what its "tensile strength may be," but I do not think sufficient importance has been given to the proportion of ductility to ultimate strength ; this proportion will be largely affected by the chemical composition of the material; that is to say, with an ultimate strength of 80 000 lbs., the ductility will vary from ten to thirty per cent., depending upon the chemical composition of the material, so that with a *given amount of ductility* the safest material for the engineer to use will almost certainly be that having the highest ultimate strength, the requirements therefore which the author has formulated for bridge steel, whilst safe, are misleading, and if expressed, as he himself has stated it in the sentence I have quoted, would have a tendency to improve the quality of the manufacture, thus, for plates, angles, channels and other shapes, an elongation of not less than twenty per cent. in eight inches, an ultimate strength of not less than 65 000 lbs., and a limit of elasticity not less than half the ultimate strengh.

The reference to the form of thread that should be used for bridge screws, is of questionable value. The truncated V form which the author condemns, is the form which our naval engineers have used for nearly 15 years, and has been almost universally adopted in the United States; the section of the metal remaining, is less reduced than with the form he recommends, whilst the angles are very obtuse; it should require conclusive experiments establishing the authors opinion to warrant a change in this particular, where uniformity has been almost attained in the direction excepted to, and it is very certain immense numbers of steel screws have been made with this form of thread without failure.

I could have wished that the author had elaborated his remarks concerning the annealing of steel as it might be inferred that all eye bars, for example, would require to be annealed, because unequally or locally heated; if locally strained from any cause, steel should be annealed, but it must be borne in mind that annealing will reduce the ultimate strength

and the limit of elasticity giving probably a corresponding increase of ductility, so that in these particulars the metal annealed will not correspond with other similar materials in other parts of the structure that are not annealed.

The density of steel is largely affected by the kind and amount of treatment the ingot receives in fashioning it to the finished shape, in this process the particles are driven closer together and the application of heat without concurrent working, will drive them apart. When, therefore, annealing is resorted to, it should be done at a very low heat and for as short a time as possible; too high a heat or too long continued, or too frequent, will produce a marked degradation of the material; indeed the injury that may result from the practice, except in the hands of an expert, is so great that it should not be tolerated in general practice. There are conditions in which annealing is indispensable to attain the best results, but these occur rarely in worked material, and with all, the ordinary workman is incompetent to deal.

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CCI.

(Vol. IX.—August, 1880.)

REMARKS ON THE CAUSES OF FALL OF THE WESTERN ARCHED APPROACH TO THE SOUTH STREET BRIDGE, PHILADELPHIA.*

By J. G. BARNARD, Hon. Mem. A. S. C. E.

The origin and circumstances of settlement of the pier No. 2, as described by Mr. Stauffer, "Transactions," September, 1878, to which is due the catastrophe, are so peculiar as to merit discussion.

The soundings which were made *subsequently* to the fall showed rock at from 36 to 40 feet below surface of the marsh over which the approach was carried. A depression in the rock surface extending from under about the middle of the northern half of the pier and beyond it northerly was filled to a depth of about 3 feet with "soft mud" mixed with gravel; next above was a stratum of very hard gravel and tough clay 7 feet thick over the mud socket, but only 3 feet thick towards the south end of the pier, where it was in immediate contact with the underlying rock. Thence, upwards, was mud, quite soft at surface, "but passing into a tough clay sometime before it reached the gravel."

* Paper CLXXI, D. McN. STAUFFER, Vol. VII., p. 264, September, 1878.

The pier rested on 84 piles driven—not to a prescribed final subsidence, but, until after repeated trials, it was *found impossible to force the pile any further*, under the blow of a 2 000-pound hammer, falling 32 feet.

A pile thus driven *ought* to exhibit "impossibility" of being forced further under almost any amount of permanent load, whereas the actual permanent load under which the pier settled was but 24 tons per pile.

Piles driven by me under the piers of the Forts Hamilton and Wadsworth wharves, with a 2 200-lb hammer and 20 feet fall, to a final subsidence of 2 inches were *calculated* to have an ultimate resistence of over 100 tons per pile, and were *intended* to bear a permanent load of 20 tons—an occasional one (yet one probably of considerable duration) of 33½ tons. The new London Bridge is said to press upon each pile of its pier foundation with a weight of 80 tons.

The attributing the yielding to loss of lateral friction by the intrusion of water as a result of "tremor in the piles caused by the heavy and constant travel over the approach," seems to me fanciful—by no means a legitimate deduction from any experimental results, and a sort of hypothesis an engineer should cautiously beware of.

There was a "tremor" indeed when a 2 000-pound hammer fell 32 feet on the heads of these piles. If *that* did not let in all the water that could *thus* be admitted, nothing could. The theory of "vibration" is carried to an extreme indeed when it is supposed that "heavy and constant travel" of carriages and wagons could extend a sensible (and water-admitting) vibration through 2 000 tons of masonry to these piles. Moreover, if the shock of such a blow did not "punch" through the crust of gravel between the bottom of the pile and the mud stratum beneath, no additional dead weight would do it. *That* suggestion is, therefore, quite untenable. Chicago buildings, on piles, have furnished just such experience. Moreover, the hypothesis of "lubrication" is something new and unsupported by any knowledge we have in connection with weight-bearing capacity of piles.

Omitting, however, his conjectural lubrication and its equally conjectural effects, and discarding the alternative of "punching" through the gravel, Mr. Stauffer is doubtless otherwise quite right in supposing that the hard crust itself settled into the soft mud beneath. The hard crust rested on the mud—a material as incompressible as water, but like water having, if confined, no other measure for its load-bearing power than the resistances of the sides of the confining envelopes. In

the case before us the envelope is the gravel stratum above the rock underneath. Gradually, doubtless, this semi-fluid was forced along between the rock and the lateral overlying strata of gravel and clay, thus allowing the superstructure to sink *pari passu* with the displacement of the mud.

It is, however, alleged, or assumed, that the structure remained quite stable for a period of "six or seven years." The pile driving was finished in September, 1870. Mr. Stauffer left after completion of the work in 1876. We are not informed what time the superstructure over these piles was completed and the full loads brought to bear on the foundations; but the bridge was completed in the latter part of 1875, and opened to travel early in 1876.

It is stated that the pier is reported "to have first begun to show signs of failing in the early part of 1877;" during the twelve months following (*i.e.*, to February, 1878,) the north end had settled 20 inches, *and had been pushed about six inches to the south*, "as if the platform and foundation and pier masonry were revolving about a point located in the south face of the approach, above the springing line of the arch."

Another peculiarity of the case is suggested by the foregoing. While the ends of the piles are so firmly held by hard gravel as to resist "repeated trials" with a 2 000-pound hammer falling 32 feet, the material which, above the gravel, surrounded the piles was soft mud, which could afford little lateral support to the piles; though while everything was in its normal condition, quite sufficient.

With one end of the pier firmly supported—the other sinking—the point of rotation of the foundation and pier, considered as a rigid mass, would naturally be the firmly (as to *vertical* motion) held south end. But this would involve a very considerable lateral (northward) motion of the continuous bridge floor above, comprising in that term the arches, spandrels, and roadway. The rigidity of the wide and continuous mass was too great to permit such motion, either by bending or rupture, whereas, the want of lateral resistance in the mud which surrounded the piles allowed lateral (southerly) motion in the foundation mass itself, accompanied by a slight *canting* of the piles.

Hence the fulcrum, or centre of motion, transferred itself from the foot of the pier-foundation to a point above—*i.e.*, as Mr. Stauffer describes it, "a point located in the south face of the approach, above the springing line of the arch."

The piles, once thrown, ever so little, out of the vertical, the weight of the superstructure exerts a component force, progressively and constantly augmenting to increase the displacement.

The fall of the structure finally ensued—not, it would seem, as a direct effect of vertical settlement merely, but from the angular displacement of the piles, reaching a limit where they could no longer offer, even temporarily, resistance to the enormous lateral thrust exerted on them. The pier finally sank down (moving southward) by the *overthrow* of the piles, as the location and condition of the parts after the fall clearly indicate.

The above view of the case differs only from Mr. Stauffer's in dissenting from his opinion (as I must do unless some record of instrumental observation exhibiting the *proof* be exhibited) as to the "stability of the structure for a period of years before falling"—unless by "stability" is only meant that the bridge did *stand* one, or two, or three years from the time the load on Pier No. 2 was imposed, without noticeable (or noticed) defect of stability.

The *original* pressure on the mud of the underlying "pocket" (*i. e.*, the weight of the overlying strata) was about 2 tons. The burden of the pier—2 000 tons—was *mainly* transmitted to the gravel stratum and thence for the northern portion to the mud. The area of gravel stratum enclosing the lower end of all the piles did not exceed 600 square feet. Hence the semi-fluid mud was subjected to an increased pressure of $3\frac{1}{3}$ tons, or, making all allowance for friction and rigidity of strata above, the augmented pressure resulting would be at least double the normal pressure.

If the "pocket" was small, the resulting motion might at first be much slower than subsequently, when its enveloping surface-area became increased by penetration between the outlying gravel and the rock.

The peculiarity of the case, that a very slight settlement would bring a lateral thrust to bear on piles, the resistance of which to this kind of pressure was only the soft mud of the upper strata, seems to account for the ultimate acceleration succeeding to the slowness of the initial motion.

The case presents an almost isolated instance of the fall of a pile-supported structure, accompanied with the *overturning of the piles*. In this aspect it deserves the attention of engineers. I recall but one other instance, that of the sinking of a pier of the bridge of Tours (France). (See article "Foundations," Johnson's Cyclopedia, by Prof. DeVolson

Wood, or the Annales des Ponts et Chaussées, 1839.) The cause (not given in the Cyclopedia article) appears to have been the want of lateral support (see the "Annales"), there being but about four feet of sand over the tufa in which the points of the piles rested, all above for four feet more upward, having been dredged away in the process of preparing the foundation, without subsequent thorough replacement. No cause in this case is given for the development of lateral pressure ; but a structure on piles thus circumstanced is, as it were, "on stilts." This is a contingency in the use of piles which deserves more attention than it has hitherto received.

The *general* character ("treacherous and unstable") of the stratification (South Street Bridge) being known, *i. e.*, mud and gravel overlying rock, *each* pile foundation of the approach became a subject, as Mr. Stauffer correctly remarks, which demanded thorough examination. Alluvial and drift foundations, like this, are notorious for their variability and for the occurrence of intrusions of clay or mud.

The "pointed iron rod" would almost certainly be stopped by the first hard gravel stratum. Failing this adequate examination, and resorting to piles as a specific for the unreliableness of the subsoil, the failure to shoe and band the piles was, I think, another error. The weight-bearing measure of piles thus driven cannot be deduced with any certainty from observation of the ultimate penetration under the blow of a known "fall" and hammer-weight ; so much living force is wasted in shattering the head, in crushing the toe, and in elastic compression of the pile itself, the unshod point stopping in hard gravel where a shod point would continue to penetrate. In the present case not only was unimpeded *penetration* desirable as furnishing the most reliable test of weight-bearing capacity, but, in uncertainty as to stratification, it was desirable to reach, if not the rock, the greatest possible depth.

Finally, this single case enforces attention to two important matters concerning pile foundations on treacherous soils hitherto, I believe, almost unnoticed. First. Well ascertained and ample weight-bearing capacity of the *piles themselves* is not alone proof that the foundation is stable. We must know *what lies below* the particular stratification in which the piles terminate. Second. We must pay so much attention to what *lies above* the same stratification as to assure ourselves that under all probable assumptions as to the way in which it may be called into play there shall be *ample lateral support*. In the case before us it seems

probable that the unequal settlement, *alone* due to the mud-pocket underlying one end of the pier, would not have caused the fall. The rotation that ensued was, by the great lateral rigidity of the bridge-floor, shifted from the lower extreme end of the foundation, where mere settlement would have placed it, to a point high above, causing thereby a powerful lateral (southward) thrust on the pile heads.

The case of Fort Livingston, La., has some interest in this connection. The work, intended to defend the entrance to Barataria Bay (from which the Mississippi River banks opposite and below New Orleans may be reached in numerous localities) is on the western extremity of a sand island (Grand Terre). The shore foundation, for a long ways west of the mouth, is made up of the sedimentary discharge of the river, the coarser materials of which, of a peculiarly fine-grained, dark-colored sand, are thrown up along the shores. The shore margins of all these islands are of this sand—hard to the foot, and though of very fine and dark-colored sand, yet otherwise quite similar to the white quartzose sand margins of the Atlantic and Gulf shores of Florida.

Before commencing the foundations a single boring was made. It showed sand to a depth of nearly 20 feet, underneath which, by an abrupt transition, was a slate-colored clay, very soft and plastic as brought up, but hardening by drying. The belief was at first entertained that so thick a stratum of sand would support the work without material settlement. In this we were disappointed. No considerable weight could be applied anywhere without producing a sensible settlement. Borings were then extended everywhere over the site, varying in their results from the first, only in showing a diminution of thickness of the sand stratum on receding from the shore—in the more remote trial pits, to 11 or 12 feet.

The inference was drawn that the settlement was due to the displacement of the very plastic underlying clay. Had it been a question of sustaining an isolated weight (as *e. g.*, a bridge pier), the resort to artificial aids might, perhaps, have been entertained. But while the settlement of the masonry (scarp and counter-scarp walls, casemates, &c., &c.), was the only thing to be deprecated, the weight of any part of these, as applied to its own foundations, formed no rule by which to estimate total effect, since the whole formed an integral which carried down, as a floor, the underlying sand stratum. Moreover, the weight of the masonry was but a fractional part of the total weight imposed on this floor ; the adja-

cent embankment (glacis, ramparts, &c.) weighing many times more than the masonry. Hence, it was believed that nothing would be gained by using piles or grillages.

Unquestionably the best precaution would have been to load all the foundations, and, before building the superstructures, to have also imposed, at least to such extent as might be practicable, the sand embankments, and await the result. To a certain degree this was actually practised; but under the belief that no very serious harm would result, and from the desirableness of continuing to completion a work in an out of the way place where an organized laboring force could not be readily discharged and brought together again, the final result of this process was not waited for.

The work was essentially finished about the year 1850, and although comprising quite an extent of casemate arches, and a very long arched counter-scarp gallery, it is stated that no serious damage has since occurred. While the operations of loading and subsequent building were going on, settlements of as much as two or three feet had been exhibited. Since that it is not improbable that there has been generally a further settlement of one or two feet. Although there was *inequality* of settlement (such as the middle portions of the scarp walls going down more than the corners), there was never exhibited an abrupt transition, and hence the exemption from dislocations of the masonry. In one case, by way of experiment, a portion of the commenced scarp wall, only two or three feet high, was loaded with the full weight it was ultimately to (directly) bear, while its prolongation was left without load. Settlement followed, but it was extended for a considerable distance along the unloaded part, so that no crack resulted.

The case of Fort Livingston has little analogy with that of the South Street Bridge; the only features in common being the existence (under very different circumstances) of a soft plastic stratum under the one supposed to be fully capable of weight-bearing. Both cases, however, illustrate effects which may ensue from the existence of soft or plastic strata beneath the hard and compressed ones, on which a structure is immediately to rest.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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CCII.

Vol. IX.—August, 1880.

NOTE ON KUTTER'S DIAGRAM.

By CHARLES H. SWAN, C. E., Member of the Society.

The author of the paper* on "The Flow of Water in Small Channels," has omitted the proof that the diagram of Plate 1, Vol. viii, correctly represents the co-efficients of Kutter's formula. It is believed, however, that a concise proof that this diagram rigorously represents the formula, and is in no respect an approximation, would greatly increase confidence in its use.

Kutter's formula is a complicated equation for obtaining the value of the velocity co-efficient c, in the well known hydraulic formula,

$$v = c\sqrt{R\,s} \tag{1}$$

Kutter's equation, in its most general form, is

$$c = \frac{y}{1 + \frac{x}{\sqrt{R}}}, \tag{2}$$

from which may be deduced the proportion

$$\frac{c}{\sqrt{R}} = \frac{y}{x + \sqrt{R}}. \tag{3}$$

The diagram of Plate 1, Vol. viii, is simply a graphical construction of this proportion, by means of similar triangles, and is, therefore, strictly accurate.

* The Flow of Water in Small Channels. R. Hering. Vol. viii, p. 1, January, 1879.

The variables x and y, being used in the diagram as co-ordinates, determine the loci of n and s, of which they both are functions.

The fact that the loci of n are straight lines radiating from a fixed point on the axis of abscissas, is of great value in plotting the diagram on a large scale. It may be proved thus :

The value of x is essentially negative with reference to the co-ordinate axes of the diagram. The equations of x and y may, therefore, be written—

$$x = -\left(a + \frac{m}{s}\right) n \tag{4}$$

$$y = a + \frac{m}{s} + \frac{l}{n} \tag{5}$$

$$\text{from which, } y = \frac{l}{n} - \frac{x}{n} \tag{6}$$

This becomes an equation of the first degree when n is constant, and indicates that the loci of n are straight lines.

The point of intersection of a locus of n with the axis of abscissas may be obtained by making $y = o$ in equation (6), giving

$$x = l \tag{7}$$

This equation is independent of the value of n, and is positive. All loci of n will therefore intersect the axis of abscissas at one point, at the right of the origin, and distant therefrom an amount equal to the numerical value of l.

For measures in meters $l = 1$, and as x and $\sqrt{R}$ are plotted to the same scale, the center of radiation is at the point where

$$\sqrt{R} = \text{unity, or 1 meter.}$$

The exact character of the curves forming the loci of s is of less consequence, but may be thus shown.

When s is constant, equations (4) and (5) may be written

$$x = -\,b\,n \tag{8}$$

$$y = b + \frac{l}{n} \tag{9}$$

Referring y to a new axis of abscissas, parallel to the original one, and distant from it an amount equal to $b = a + \frac{m}{s}$, we have for the new value of y

$$y, = \frac{l}{n} \tag{10}$$

combining equations (8) and (10), we have the equation of the loci of s

$$x\ y\ y, = -\,b\,l \text{ (a constant)} \tag{11}$$

This is the equation of an hyperbola referred to its center and asymptotes, which being at right angles to each other, by construction, cause the loci of s to be equilateral hyperbolas having the axis of ordinates as a common asymptote. The asymptote parallel to the axis of abscissas has a different position for each curve, determined by the equation

$$y_2 = a + \frac{m}{s}. \qquad (12)$$

The annexed table of co-ordinates was prepared by the writer while making a draught of Kutter's diagram, on a large scale, for the City Engineer's office at Providence, R. I. It contains values of x and y, for measures in *meters*, which may be used for extending the range of Plate 1.

The metric values of x and y, given in this table, may be plotted on a diagram adapted to measures in English feet, by the following simple process.

The scales for plotting the values of x, y, $\sqrt{R}$, and c, having been determined for measures in feet, prepare two auxiliary scales, upon separate strips of paper, by which to plot the metric values of x and y.

The scale for metric values of x is made by marking upon one of the strips, the length corresponding to $x = 1.8113$ at the scale chosen for plotting x for measures in *feet*. This length is to be divided into 100 equal parts and numbered consecutively from 0. to 1., forming a scale of hundredths.

The scale for metric values of y is made by marking upon the other strip, the length corresponding to $y = 181.13$ at the scale chosen for plotting y for measures in *feet*. This length is to be divided into 100 equal parts and numbered consecutively from 0. to 100., forming a scale of units.

The writer has also prepared a series of diagrams for directly determining the dimensions of sewers, based upon the formula of Ganguillet and Kutter.

Copies of the most important diagrams are herewith presented.

NOTE.—These copies are deposited at the Rooms of the Society.

Table of Co-ordinates.

Values, for measures in meters, of x and y in the equation $c = \frac{y}{1+\frac{x}{\sqrt{A}}}$.

S	n=0.008		n=0.009		n=0.010		n=0.011		n=0.012		n=0.013		n=0.014		n=0.015		n=0.016		n=0.017		n=0.018		n=0.019		n=0.020		n=0.021		n=0.022		n=0.023		n=0.024	
	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x
0.000025											161.92	1.1650	156.43	1.1900	151.67	1.2150																				
0.000030																																		
0.000035																																		
0.000040																																		
0.000045																																		
0.000050																																		
0.000055																																		
0.000060																																		
0.000065																																		
0.000070																																		
0.000075																																		
0.000080																																		
0.000085																																		
0.000090																																		
0.000095																																		
0.00010	163.50	0.3080	149.61	0.3435	138.50	0.3850	129.41	0.4235	121.83	0.4620	115.42	0.5005	109.93	0.5390	105.17	0.5775	101.00	0.6160	97.32	0.6545	94.06	0.6930	91.13	0.7315	88.50	0.7700	86.12	0.8085	83.95	0.8470	81.98	0.8855	80.17	0.9240
0.00012	160.92	0.2973	147.03	0.3233	135.92	0.3592	126.63	0.3951	119.25	0.4310	112.84	0.4669	107.35	0.5028	102.58	0.5388	98.46	0.5747	94.76	0.6106	91.47	0.6465	88.55	0.6824	85.92	0.7183	83.54	0.7543	81.37	0.7902	79.39	0.8261	77.58	0.8620
0.00015	158.33	0.2661	144.44	0.3000	133.33	0.3333	124.24	0.3661	116.67	0.4000	110.26	0.4333	104.76	0.4667	100.00	0.5000	95.83	0.5333	92.16	0.5667	88.89	0.6000	85.96	0.6333	83.33	0.6667	80.95	0.7000	78.79	0.7333	76.81	0.7667	75.00	0.8000
0.00020	155.75	0.2460	141.86	0.2787	131.06	0.3075	121.66	0.3382	114.08	0.3690	107.67	0.3997	102.12	0.4305	97.42	0.4613	93.25	0.4920	89.57	0.5227	86.31	0.5535	83.38	0.5842	80.75	0.6150	78.37	0.6457	76.20	0.6765	74.23	0.7072	72.42	0.7380
0.00025	153.17	0.2253	139.28	0.2535	129.12	0.2817	119.08	0.3098	111.50	0.3380	105.09	0.3662	99.60	0.3945	94.83	0.4225	90.67	0.4507	86.99	0.4788	83.72	0.5070	80.80	0.5352	78.17	0.5633	75.79	0.5915	73.61	0.6197	71.66	0.6478	69.83	0.6760
0.00030	151.87	0.2150	137.99	0.2419	126.87	0.2687	117.78	0.2956	110.21	0.3225	103.90	0.3494	98.50	0.3763	93.84	0.4031	89.87	0.4300	86.20	0.4569	82.93	0.4838	79.91	0.5106	77.28	0.5375	74.99	0.5644	72.93	0.5913	70.95	0.6181	69.14	0.6450
0.00035	151.10	0.2088	137.21	0.2349	126.10	0.2610	117.01	0.2871	109.43	0.3132	103.02	0.3393	97.53	0.3654	92.77	0.3915	88.60	0.4176	84.92	0.4437	81.64	0.4698	78.73	0.4959	76.10	0.5220	73.72	0.5481	71.56	0.5742	69.58	0.6003	67.77	0.6264
0.00040	150.58	0.2047	136.69	0.2302	125.58	0.2558	116.49	0.2814	108.92	0.3070	102.51	0.3326	97.01	0.3581	92.25	0.3837	88.08	0.4093	84.40	0.4349	81.14	0.4605	78.21	0.4861	75.58	0.5117	73.20	0.5372	71.04	0.5628	69.06	0.5884	67.25	0.6140
0.00045	150.21	0.2012	136.32	0.2269	125.21	0.2521	116.12	0.2774	108.55	0.3026	102.14	0.3278	96.64	0.3530	91.88	0.3782	87.71	0.4034	84.04	0.4286	80.77	0.4539	77.84	0.4791	75.21	0.5043	72.83	0.5295	70.67	0.5547	68.69	0.5799	66.88	0.6051
0.00050	149.84	0.1995	136.05	0.2246	124.94	0.2496	115.87	0.2745	108.27	0.2995	101.86	0.3245	96.37	0.3494	91.60	0.3744	87.44	0.3993	83.76	0.4243	80.50	0.4492	77.57	0.4742	74.94	0.4991	72.56	0.5241	70.40	0.5490	68.43	0.5740	66.62	0.5989
0.00055	149.72	0.1978	135.83	0.2225	124.72	0.2472	115.63	0.2719	108.06	0.2967	101.64	0.3214	96.15	0.3461	91.39	0.3708	87.22	0.3956	83.54	0.4203	80.28	0.4450	77.35	0.4697	74.72	0.4944	72.34	0.5192	70.18	0.5439	68.23	0.5686	66.39	0.5933
0.00060	149.55	0.1964	135.66	0.2210	124.53	0.2455	115.46	0.2700	107.88	0.2946	101.47	0.3191	95.98	0.3437	91.22	0.3683	87.05	0.3929	83.37	0.4173	80.11	0.4419	77.18	0.4664	74.55	0.4910	72.17	0.5156	70.00	0.5401	68.05	0.5646	66.22	0.5892
0.00070	148.77	0.1902	134.89	0.2140	123.77	0.2377	114.68	0.2615	107.11	0.2853	100.70	0.3091	95.20	0.3329	90.44	0.3566	86.27	0.3804	82.60	0.4042	79.33	0.4280	76.41	0.4517	73.77	0.4755	71.39	0.4993	69.23	0.5231	67.25	0.5468	65.44	0.5706
0.00080	148.39	0.1871	134.50	0.2105	123.39	0.2339	114.30	0.2573	106.72	0.2806	100.31	0.3040	94.82	0.3274	90.05	0.3508	85.89	0.3742	82.21	0.3976	78.96	0.4210	76.02	0.4443	73.39	0.4677	71.01	0.4911	68.84	0.5145	66.86	0.5378	65.05	0.5613
0.00090	148.26	0.1861	134.37	0.2093	123.26	0.2326	114.17	0.2558	106.59	0.2791	100.18	0.3024	94.69	0.3256	89.92	0.3489	85.76	0.3721	82.08	0.3954	78.81	0.4187	75.88	0.4419	73.26	0.4652	70.88	0.4884	68.71	0.5117	66.74	0.5349	64.92	0.5582
0.00100	148.19	0.1856	134.30	0.2087	123.19	0.2319	114.10	0.2551	106.53	0.2783	100.12	0.3015	94.62	0.3247	89.86	0.3479	85.69	0.3711	82.02	0.3943	78.75	0.4175	75.82	0.4407	73.19	0.4639	70.81	0.4871	68.65	0.5103	66.67	0.5335	64.86	0.5567
0.0100	148.15	0.1852	134.26	0.2083	123.15	0.2315	114.06	0.2546	106.48	0.2778	100.07	0.3009	94.58	0.3241	89.82	0.3473	85.65	0.3704	81.97	0.3935	78.70	0.4167	75.75	0.4398	73.15	0.4630	70.77	0.4861	68.60	0.5093	66.63	0.5324	64.82	0.5556
0.1000	148.01	0.1841	134.13	0.2071	123.01	0.2301	113.92	0.2532	106.35	0.2762	99.94	0.2992	94.44	0.3222	89.68	0.3452	85.51	0.3682	81.84	0.3912	78.57	0.4143	75.65	0.4373	73.01	0.4603	70.63	0.4833	68.47	0.5063	66.49	0.5293	64.68	0.5524
1.0000	148.00	0.1840	134.11	0.2070	123.00	0.2300	113.91	0.2531	106.33	0.2760	99.92	0.2990	94.43	0.3220	89.67	0.3450	85.50	0.3680	81.82	0.3910	78.56	0.4140	75.63	0.4370	73.00	0.4600	70.61	0.4830	68.46	0.5060	66.48	0.5290	64.67	0.5521

S	n=0.025		n=0.026		n=0.027		n=0.028		n=0.029		n=0.030		n=0.031		n=0.032		n=0.033		n=0.034		n=0.035		n=0.036		n=0.037		n=0.038		n=0.039		n=0.040		n=0.041	
	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x
0.000060	88.83	1.2208																																
0.000065	86.85	1.1711	85.31	1.2150																														
0.000070	85.14	1.1286	83.60	1.1737	82.18	1.2189																												
0.000075	83.67	1.0917	82.13	1.1356	80.73	1.1790	79.58	1.2227																										
0.000080	82.31	1.0594	80.84	1.1018	79.41	1.1441	78.09	1.1861	76.86	1.2289																								
0.000085	81.23	1.0309	79.70	1.0721	78.27	1.1133	76.95	1.1544	75.72	1.1958	74.51	1.2370																						
0.000090	80.22	1.0055	78.68	1.0455	77.26	1.0860	75.94	1.1262	74.70	1.1664	73.56	1.2066	72.46	1.2469																				
0.000095	79.32	0.9829	77.78	1.0222	76.35	1.0615	75.03	1.1005	73.80	1.1402	72.65	1.1795	71.57	1.2188	70.51	1.2581																		
0.00010	78.50	0.9625	76.96	1.0010	75.54	1.0395	74.21	1.0777	72.98	1.1165	71.83	1.1550	70.76	1.1935	69.75	1.2320	68.80	1.2705																
0.00012	75.92	0.8919	74.38	0.9339	72.95	0.9698	71.63	1.0058	70.40	1.0416	69.25	1.0775	68.17	1.1134	67.17	1.1493	66.21	1.1853	65.33	1.2212	64.49	1.2571												
0.00015	73.33	0.8333	71.79	0.8667	70.37	0.9000	69.05	0.9333	67.82	0.9667	66.67	1.0000	65.59	1.0333	64.58	1.0667	63.64	1.1000	62.75	1.1333	61.90	1.1666	61.11	1.2000	60.36	1.2333								
0.00020	70.15	0.7681	68.21	0.7995	67.19	0.8302	65.93	0.8598	64.78	0.8915	63.71	0.9231	62.70	0.9546	61.75	0.9861	60.86	1.0176	60.02	1.0491	59.21	1.0761	58.93	1.1070	57.78	1.1371	57.01	1.1685	56.29	1.1992	55.75	1.2300		
0.00025	68.11	0.7042	66.03	0.7324	65.10	0.7605	63.88	0.7885	62.85	0.8168	61.80	0.8446	60.84	0.8731	59.96	0.9013	59.14	0.9295	58.37	0.9576	57.64	0.9855	56.94	1.0140	55.18	1.0421	54.48	1.0704	53.81	1.0985	53.11	1.1267	52.56	1.1548
0.00030	66.57	0.6719	65.34	0.6988	63.91	0.7256	62.69	0.7525	61.56	0.7794	60.51	0.8062	59.53	0.8331	58.62	0.8600	57.78	0.8869	56.99	0.9138	55.45	0.9406	54.65	0.9675	53.90	0.9944	53.19	1.0213	52.52	1.0481	51.87	1.0750	51.26	1.1019
0.00035	66.10	0.6523	64.96	0.6786	63.14	0.7047	61.91	0.7308	60.58	0.7569	59.43	0.7830	58.36	0.8090	57.35	0.8351	56.40	0.8612	55.51	0.8873	54.66	0.9135	53.85	0.9396	53.13	0.9657	52.41	0.9918	51.74	1.0179	51.10	1.0440	50.49	1.0701
0.00040	65.59	0.6396	64.04	0.6652	62.61	0.6907	61.30	0.7163	60.07	0.7419	58.92	0.7675	57.84	0.7931	56.83	0.8187	55.89	0.8442	54.99	0.8698	54.15	0.8954	53.36	0.9210	52.61	0.9466	51.90	0.9722	51.22	0.9977	50.58	1.0233	49.97	1.0489
0.00045	65.21	0.6304	63.68	0.6556	62.31	0.6808	60.93	0.7060	59.70	0.7312	58.55	0.7564	57.47	0.7816	56.46	0.8068	55.52	0.8321	54.63	0.8573	53.78	0.8825	52.99	0.9077	52.24	0.9329	51.53	0.9581	50.85	0.9833	50.21	1.0086	49.60	1.0338
0.00050	64.94	0.6234	63.40	0.6484	61.97	0.6733	60.65	0.6982	59.42	0.7232	58.27	0.7481	57.20	0.7730	56.19	0.7980	55.24	0.8229	54.35	0.8479	53.51	0.8728	52.71	0.8977	51.96	0.9227	51.25	0.9476	50.58	0.9725	49.94	0.9975	49.33	1.0224
0.00060	64.72	0.6160	63.18	0.6408	61.76	0.6655	60.44	0.6902	59.20	0.7150	58.05	0.7416	56.98	0.7644	55.97	0.7891	55.02	0.8139	54.13	0.8386	53.29	0.8633	52.50	0.8880	51.75	0.9127	51.04	0.9374	50.36	0.9621	49.72	0.9869	49.11	1.0116
0.00070	64.55	0.6157	63.01	0.6383	61.59	0.6629	60.26	0.6874	59.03	0.7120	57.88	0.7365	56.81	0.7611	55.80	0.7856	54.85	0.8101	53.96	0.8347	53.12	0.8592	52.33	0.8838	51.58	0.9083	50.87	0.9329	50.19	0.9574	49.55	0.9820	48.94	1.0065
0.00080	63.71	0.5946	62.24	0.6182	62.81	0.6419	59.49	0.6657	58.26	0.6895	57.11	0.7132	56.03	0.7370	55.02	0.7608	54.08	0.7846	53.19	0.8084	52.35	0.8321	51.55	0.8559	50.80	0.8797	50.09	0.9035	49.42	0.9272	48.78	0.9510	48.18	0.9748
0.00090	63.39	0.5867	61.85	0.6081	60.42	0.6314	59.10	0.6548	57.87	0.6781	56.72	0.7016	55.64	0.7250	54.64	0.7484	53.69	0.7718	52.80	0.7952	51.96	0.8185	51.16	0.8419	50.41	0.8653	49.70	0.8887	49.03	0.9121	48.39	0.9355	47.78	0.9589
0.00100	63.26	0.5814	61.72	0.6042	60.29	0.6280	58.97	0.6513	57.74	0.6746	56.59	0.6977	55.52	0.7210	54.51	0.7443	53.56	0.7675	52.67	0.7908	51.83	0.8140	51.04	0.8373	50.28	0.8605	49.57	0.8838	48.90	0.9071	48.26	0.9303	47.65	0.9536
0.00120	63.19	0.5708	61.66	0.6031	60.23	0.6262	58.91	0.6494	57.68	0.6726	56.53	0.6958	55.46	0.7190	54.46	0.7422	53.52	0.7654	52.61	0.7886	51.76	0.8118	50.97	0.8350	50.22	0.8582	49.51	0.8814	48.83	0.9046	48.19	0.9278	47.58	0.9509
0.00140	63.15	0.5787	61.61	0.6019	60.19	0.6250	58.86	0.6482	57.63	0.6714	56.48	0.6946	55.41	0.7178	54.40	0.7409	53.46	0.7641	52.56	0.7873	51.72	0.8105	50.93	0.8336	50.18	0.8568	49.47	0.8799	48.79	0.9031	48.15	0.9262	47.54	0.9494
0.00160	63.01	0.5754	61.48	0.5984	60.05	0.6214	58.73	0.6444	57.50	0.6674	56.35	0.6904	55.27	0.7135	54.26	0.7365	53.31	0.7595	52.43	0.7825	51.59	0.8055	50.79	0.8285	50.04	0.8516	49.34	0.8746	48.67	0.8976	48.03	0.9206	47.42	0.9436
1.0000	63.00	0.5750	61.46	0.5980	60.04	0.6210	58.71	0.6440	57.48	0.6670	56.33	0.6900	55.26	0.7130	54.25	0.7360	53.30	0.7590	52.41	0.7820	51.57	0.8050	50.78	0.8280	50.03	0.8510	49.32	0.8740	48.64	0.8970	48.00	0.9200	47.39	0.9430

S	n=0.042		n=0.043		n=0.044		n=0.045		n=0.046		n=0.047		n=0.048		n=0.049		n=0.050	
	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x
0.0003	51.98	1.1830	51.42	1.2112	50.89	1.2393												
0.0004	50.68	1.1288	50.13	1.1556	49.60	1.1825	49.10	1.2094	48.61	1.2362	48.15	1.2631						
0.0005	49.91	1.0961	49.36	1.1223	48.83	1.1484	48.32	1.1745	47.84	1.2006	47.38	1.2267	46.93	1.2528				
0.0006	49.39	1.0745	48.84	1.1001	48.31	1.1256	47.80	1.1512	47.32	1.1768	46.86	1.2024	46.42	1.2280	45.99	1.2536		
0.0007	49.02	1.0590	48.47	1.0842	47.94	1.1094	47.44	1.1346	46.95	1.1598	46.49	1.1851	46.05	1.2103	45.62	1.2355		
0.0008	48.75	1.0474	48.19	1.0723	47.66	1.0971	47.16	1.1220	46.68	1.1471	46.21	1.1721	45.77	1.1970	45.34	1.2219	44.94	1.2468
0.0009	48.53	1.0383	47.98	1.0631	47.45	1.0878	46.94	1.1125	46.46	1.1371	46.00	1.1618	45.56	1.1866	45.13	1.2114	44.72	1.2361
0.0010	48.34	1.0311	47.81	1.0557	47.28	1.0803	46.77	1.1049	46.29	1.1295	45.83	1.1539	45.38	1.1784	44.96	1.2029	44.55	1.2275
0.0020	47.58	0.9986	47.03	1.0223	46.52	1.0461	46.02	1.0699	45.54	1.0937	45.08	1.1176	44.64	1.1412	44.18	1.1650	43.77	1.1887
0.0040	47.20	0.9823	46.64	1.0056	46.11	1.0290	45.61	1.0524	45.13	1.0758	44.68	1.0992	44.22	1.1226	43.78	1.1460	43.37	1.1693
0.0060	47.07	0.9769	46.51	1.0001	45.98	1.0233	45.48	1.0466	45.00	1.0699	44.53	1.0931	44.09	1.1164	43.67	1.1395	43.26	1.1629
0.0080	47.00	0.9742	46.45	0.9973	45.91	1.0205	45.42	1.0437	44.93	1.0669	44.47	1.0900	44.03	1.1133	43.60	1.1365	43.19	1.1597
0.0100	46.96	0.9733	46.41	0.9965	45.88	1.0196	45.37	1.0427	44.89	1.0659	44.43	1.0891	43.98	1.1122	43.56	1.1353	43.15	1.1585
0.0120	46.92	0.9666	46.37	0.9891	45.84	1.0116	45.34	1.0341	44.85	1.0567	44.39	1.0817	43.95	1.1042	43.52	1.1277	43.01	1.1507
1.0000	46.81	0.9661	46.28	0.9890	45.73	1.0120	45.22	1.0350	44.74	1.0580	44.28	1.0811	43.83	1.1040	43.41	1.1270	43.00	1.1500

Formulas.

$$y = 23 + \frac{0.00155}{S} + \frac{1}{n} .$$

$$x = ny - 1 .$$

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

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CCIII.

(Vol. IX.—September, 1880.)

TENSILE TESTS OF CEMENT, AND AN APPLIANCE FOR MORE ACCURATE DETERMINATIONS.

By D. J. Whittemore, Member of the Society.

Read at the Twelfth Annual Convention, May 25th, 1880.

With Discussion by William P. Shinn, M. Coryell, Ashbel Welch, James B. Francis, James B. Eads, J. H. Harlow, Max E. Schmidt, E, S. Chesbrough, William R. Hutton, F. O. Norton and D. J. Whittemore.

For the purpose of ascertaining tensile strength, Lipowitz of Germany, in his work on Portland Cement, advises the use of briquettes having a form and size of breaking section 3 x 6 centimetres.

I understand that the area of rupture used by French Engineers is commonly 4 x 4 centimetres, though an area of 3 x 4 centimetres is sometimes employed.

In England the usual size is $1\frac{1}{2}$ x $1\frac{1}{2}$ inches. This size is extensively used by Engineers in this country. Sometimes the form is changed, keeping the area the same. Manufacturers of hydraulic cements in this country are using largely a breaking area of 1 inch square.

Many of the published statements we have, give the tensile strength per square unit of measure, omitting to mention the actual size of the briquette.

One of the objects of this paper is to show the importance of knowing the actual linear measure of the breaking section, and to consider whether, in comparison of results determined from briquettes of different sizes, some more satisfactory and correct unit of measure can be employed than the expression of area now so universally used. It is known to many experimenters that, in tensile tests particularly, the apparent strength per square unit of ruptured area is greater in small than in large briquettes, and in an endeavor to determine the ratio of this apparent variation I have made certain tests, in which investigation I employed cylindrical briquettes of two sizes, the larger one having a breaking section of two square inches, and a form and clutch appliance similar to that shown in my notes on Alfred Noble's paper of last year.* The smaller briquette and clutch is shown by plate herewith annexed. The breaking area of this briquette is one-half of one square inch, and its form and clutch, in my opinion, possess marked features of excellence. (See Plate XVII.)

It will be seen that each head of this briquette has its principal enlargement at three equi-distant places upon its circumference—each enlargement comprising an arc of about 58 degrees. The lower half of the face of these projections forms part of the surface of a sphere, the center of which is upon the axis of the briquette. The gimbal clutch has slots cut from the intrados of the inner gemel-ring of a size sufficient to allow the head of the briquette to pass through. The balance of the intrados is truly turned to fit the surfaces of the briquette enlargement, and when the briquette is inserted a proper distance and revolved about 60 degrees a secure and perfectly fitting seat is provided upon the inner gemel-ring.

To secure uniformity in moulding specimens I have designed a press by which, after the flask is charged with mortar, plungers act upon each end of the mass with some definite pressure. The annexed sketch shows this device, and needs no further description to understand its operation. (See Plate XVIII.)

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* Experiments with Appliances for Testing Cement, by Alfred Noble, Vol. IX., p. 186. Discussion by D. J. Whittemore, p. 199 (May, 1880).

The uniformity in tests by this arrangement of moulding and application of gimbals to the clutch is so remarkable that I will here state the first series of tests made with its use.

The mortar was made of neat cement, which was first mixed thoroughly, so as to be quite certain that any part should be an exponent of the whole. All samples were brought to the same degree of plasticity, and moulded under the same pressure, and when set removed from the flask and placed in water for a period of seven days—then tested, with the following results;

TABLE No. 1.

No. of Test.	Tensile Strength of Briquette.	Strength per Square Inch.	Per Cent. Variation from Mean.
	Lbs.	Lbs.	
1	74.06	148.12	2.8
2	69.69	139.38	3.9
3	69.69	139.38	3.9
4	75.31	150.62	3.9
5	72.81	145.62	0.4
6	71.56	143.12	1.3
7	73.13	146.26	0.9
8	73.13	146.26	0.9
Average	72.42	144.84	2.25

The average variation from the mean here shown is only about one-quarter of that I usually obtain by the use of my modified form of the common briquette, and less than one-half that ordinarily obtained by the use of the circular briquette of two square inches breaking area and cup clutch. Believing that any instrument devised for purely scientific purposes should never be patented I freely offer the design to all who may now or hereafter desire to make use of it.

For the purpose of conducting the inquiry first alluded to I selected four of the typical brands of American hydraulic cements used in the northern, western and south-western portions of this country, also one

sample of English Portland. The American brands selected were Norton's Rosendale, Buffalo, Louisville and Milwaukee. It is not the purpose of this paper to permit any invidious comparisons to be made as to the quality of any known brand. I shall, therefore, designate these samples by numbers, not, however, consecutively in the order named above. The following table gives the analyses of these cements:

TABLE No. 2.

No. of Cement.	Carbonic Acid.	Lime.	Magnesia.	Silica.	Aluminum.	Oxide of Iron.	Alkalin Water. Loss, &c.
1.....	3.06	45.17	16.52	23.40	8.07	2.45	1.33
2.....	6.48	36.32	14.47	24.50	14.32	2.93	0.98
3.....	4.37	33.97	15.21	28.04	12.82	4.60	0.99
4.....	0.96	40.75	25.25	22.22	8.68	1.18	0.96
Portland....	0.45	63.44	1.34	22.98	6.88	3.80	1.11

The following table shows the weight of the cements as determined by the method described in my remarks on Mr. Maclay's paper (Transactions, Vol. VII, page 275).

Fineness is expressed in the per cent. rejected by sieve of 60 meshes to the linear inch, wire No. 36. The last column shows the amount of water required in terms of per cent. by weight of cement to make all mortars of the same degree of plasticity.

TABLE No. 3.

No. of Cement.	Weight, Grains per cubic inch.	Per Cent., Rejected by No. 60 Sieve.	Water Used, Per Cent.
1.....	328.5	29.2	39.6
2....	333.5	10.5	38.7
3....	361.8	3.5	33.9
4.....	394.3	8.5	31.2
Portland...	453.0	16.6	24.2

Since American hydraulic cements vary 20 per cent. in weight, it is almost impossible to devise any expression, referring to weight alone, that will determine what quantity of water is required to produce mortars of a uniform degree of plasticity. I have also failed as yet to determine any exact relation from bulk measurement for this purpose. Undoubtedly, the quantity of water required is somewhat dependent upon the fineness of the cement used.

The amount of water used was sufficient to render the mortar plastic under a vigorous use of the hoe, producing what may be termed over-stiff mason's mortar. Enough cement was mixed at one operation to make a briquette of each size. Four of each size and kind were so made, and subjected in the flask to the same pressure per unit of end area of briquette. When the mortars had set, each sample was immediately placed in water of a uniform temperature of 66° F., for a period of 7 days, and then tested.

The following table gives the average of four tests in each instance:

TABLE No. 4.

	Circular Briquette Breaking Area, 2 Square Inches.			Circular Briquette Breaking Area, ½ Square Inch.		
	1	2	3	4	5	6
No. of Mortor.	Total Tensile Strength. Lbs.	Tensile Strength per sq. inch. Lbs.	Tensile Strength per lin. inch of Circumference. Lbs.	Total Tensile Strength. Lbs.	Tensile Strength per sq. inch. Lbs.	Tensile Strength per lin. inch of Circumference. Lbs.
1	106.00	53 00	21.20	41.60	83.20	16.64
2	104.20	52.10	20.84	54.40	108.80	21.76
3	127.76	63.88	25.56	72.42	144.84	28.97
4	107.81	53.90	21.56	53.12	106.24	21.25
Average	.....	55.72	22.29	.....	110.77	22.15
Portland	619.20	309.60	123.84	292.70	585.40	117.08

From the above it is seen that the apparent strength per square inch of the smaller briquette is about double that of the larger. Taking the average of the aggregate of results from the American product, it appears almost exactly so. What measure of the breaking section of the two sizes of briquettes is, then, most nearly proportional to their strength ? Not the area ; but a glance will show that either the diameter or periphery of the breaking section is about proportional to the ultimate strength. The variation from this rule is shown in columns Nos. 3 and 6, in which the strength per linear inch of circumference is determined by dividing the total strength of each briquette by the periphery of the breaking section.

Casting about for some corroborative testimony, deduced from the determination of other experimenters, I find that John Grant, M. Inst. C. E., in his work "On the Strength of Cement," page 124, gives the results of an extended series of tests instituted for the purpose of determining the form and size of briquettes that should be adopted in conducting his tests. Neglecting his forms Nos. 1 and 2, which have no counterparts of different breaking areas, I give in the following table his results on Portland cement, with four forms, having a breaking area of $1\frac{1}{2} \times 1\frac{1}{2}$ inches, and four other almost similar forms having a breaking area of 2×2 inches. The results from similar forms, but of different sizes, I place upon the same line in the table.

The moulded samples were from the same cement and were kept in water for the time mentioned. The results given are the average of ten tests in each instance.

In the following table I have introduced the column representing the strength per linear inch of circumscribing line of breaking section of each briquette, and the amounts so ascertained approximate closely to each other, while the strength per square inch varies about as 4 is to 3.

Taking the average of all the determinations at 7 and 30 days of peripheric strength, and we have for the $1\frac{1}{2} \times 1\frac{1}{2}$ inches section 161.6 lbs. per linear inch, and for the 2×2 inches section 161.7 lbs. per linear inch.

This relation of equal peripheric strength is not mentioned in Grant's work. The evidence of its truth, however, is so strong when applied to tests of samples of the age mentioned, and varying in size from $\frac{1}{2}$ of one square inch up to 4 square inches, that any expression of strength of cements per square unit of breaking area is of little value, unless such statement is accompanied by the dimensions of the briquette tested.

TABLE No. 5.

STRENGTH OF BRIQUETTES, $1\frac{1}{2} \times 1\frac{1}{2}$ INCHES.

No. of Form.	7 Days.			30 Days.		
	Total lbs.	Per sq. inch. Lbs.	Per lin. inch. Lbs.	Total lbs.	Per sq. inch. Lbs.	Lbs.
3	1064.3	473.0	177.4	1145.4	509.0	190.9
4	918.9	408.4	153.1	969.0	430.7	161.5
5	924.0	410.6	154.0	967.0	429.8	161.2
6	860.0	382.2	143.3	912.0	405.4	152.0
Average		418.5	156.9		443.7	166.4

STRENGTH OF BRIQUETTES, 2 x 2 INCHES.

No. of Form.	7 Days.			30 Days.		
	Total lbs.	Per sq. inch. Lbs.	Per lin. inch. Lbs.	Total lbs.	Per sq. inch. Lbs.	Per lin. inch. Lbs.
10	1286.3	321.6	160.8	1460.3	365.0	182.5
7	1199.2	300.0	149.9	1354.7	338.7	169.3
8	1172.6	293.0	146.6	1315.1	328.8	164.4
9	1190.5	297.6	148.8	1371.2	342.8	171.4
Average		303.0	151.5		343.8	171.9

In view of these results, it is but natural I should conceive it possible that the surface of the specimens had acquired a tenacity not extending throughout the entire mass, and that a surface hardening had taken

place through some process of crystallization, or by the absorption of carbonic acid, forming a sub-carbonate.

Having witnessed the remarkable effects of the so-called carbonization process in the manufacture of cement sewer-pipe, and having tested many samples of cement mortar that had been subjected to the process, I was prepared to believe that this same effect might be produced to some extent in ordinary water exposures.

The so-called process of carbonization is executed as follows:

In a chamber constructed of a double thickness of two-inch plank, the joints of which are tongued, grooved and painted so as to render the same nearly air tight, is placed the moulded pipe as soon as removed from the flasks. Outside the chamber is a furnace for burning charcoal, the exit pipe of which, for conveying the product of combustion, is brought to, and terminates in, the centre of said chamber. Over the fire of the furnace is a small boiler for generating steam, and the steam so generated is carried by an escape pipe into the pipe conveying the product of combustion to the carbonizing chamber. The size of the chamber in this instance is sufficient to conveniently store pipe produced from the use of from 13 000 to 15 000 lbs. of cement. When the charcoal is ignited the absorption takes place with sufficient vigor, if the supply of steam is properly regulated, to maintain combustion for a period of about six days, when the burning charcoal smothers and dies out from insufficient draft. The amount of charcoal consumed in this time is about 2-$\frac{1}{2}$ lbs. to 100 lbs. cement in the chamber. Making due allowance for other matter than carbon in charcoal, this would show that if all the carbonic acid was absorbed by the cement, a saturation of from 5 to 7 per cent. had taken place. If from any cause the supply of steam be not sufficient, and the surface of the cement samples become dry, the absorptive process is arrested, and any subsequent steaming will not observably restore it. Again, should the supply become excessive, so as to produce absolute wetness upon the floor of the chamber, absorption is also arrested and the fire goes out. So delicate is this matter of steam supply that an allowance must be made for the hydrometric conditions of the outside atmosphere. In other words, less steam is required in wet than in dry weather.

Crushing tests on pipe subjected to this process, and on pipe made from same moulds, same cements, and *not* so subjected, have been made, many of which tests I have observed myself, and believe to have been

fairly conducted. The first were subjected, during the first six days to the carbonizing process, and then stored in sheds along with the uncarbonized.

The following table gives the results of one series of such experiments, each result being an average of two tests :

TABLE No. 6.

Age.	Carbonized.	Not Carbonized.
15 days.	2 979 lbs.	2 083 lbs.
45 "	2 871 "	2 691 "
75 "	3 329 "	3 168 "
105 "	3 622 "	3 454 "
137 "	3 901 "	3 779 "

These determinations indicate simply a hastening of the indurating action. Briquettes of many different brands of cement that I have placed in the carbonizing chamber for a period of from 50 to 60 days have shown double the tensile strength of those kept in water for the same length of time. Others have shown no increase whatever, but generally there is a marked gain. With these facts before me, I conceived it possible that water might absorb carbonic acid from the atmosphere, and afterwards impart it to samples of cements immersed therein, resulting in a coating of the briquettes with a sub-carbonate of considerable strength. To determine this, I instituted the following tests :

Of the five samples of cement before alluded to there were moulded eight briquettes of each. Four of these were placed in open jars filled with water, and common water was used in the initial mixture. For the other four, distilled water was used both in mixture and exposure, the latter being in glass tubes hermetically sealed. *In one of these tubes was placed a thermometer.* The samples in the open jars gave off the usual amount of *baitance*, while those in the tubes gave off none, so far as the eye could determine, to the end. There was, however, an efflux in the form of crystals thickly studding the surface of the briquettes,

and of sufficient size and quality to permit of collection for analysis. They proved to be crystals of hydrate of lime.

Exposure to the atmosphere soon converted a thin scale of their surface to a carbonate

At the expiration of 40 days all the samples were tested, and a cutting taken from off the broken section of those exposed in open jars for an analytical determination of the carbonic acid absorbed. The following tables gives the average of each of the four tests. The briquette used was that with the rupturing area of ½ of one square inch.

TABLE No. 7.

Kind of Cement.	Average Tensile Strength of Briquette, Hermetically Sealed.	Average Tensile Strength of Briquette, In Open Glass Jars.	Per Cent. Carbonic Acid Absorbed.
No. 1.....	178.20	169.45	0.10
2.....	216.00	158.81	0.0
3.....	204.76	169.28	.00
4	190.20	153.54	0.39
Portland	277.57	316.64	1.06

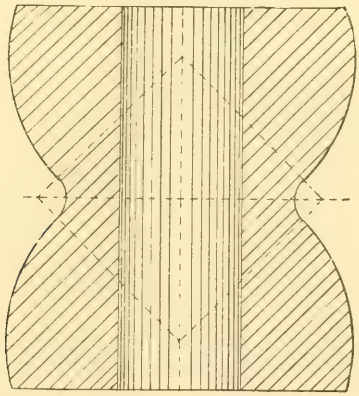
From the above showing, I do not feel assured that any of the American cements absorbed carbonic acid to any extent whatever, while the Portland did to the amount of about one per cent. The average greater strength of the American cements in sealed tubes, over those of the same kind in open jars, is about 21 per cent., but the reverse is the case with Portland, which undoubtedly absorbed some carbonic acid when exposed in water in open jars. The deduction I am forced to make is, that there is no appreciable formation of sub-carbonates upon the surface of American cements exposed in unsealed water at an age of 7 or even 40 days, but how can we account for the remarkable advance in strength of these cements that were enclosed in sealed tubes, over those that were not ?

Perhaps the thermometer will inform us. The temperature of the water in the open jars subject to evaporating influences was quite uniformly 66° F., while that in the sealed tubes was from 3½ to 6

degrees higher, though all were kept in the same room. Under the influence of this greater temperature the Portland did not increase in strength, but fell behind those of the same kind in the open jars. Perhaps the slight carbonization that occurred in these more than counteracted the favorable elevation of temperature in the former.

In the light of these tests might it not be conceived that a portion of the remarkable effect of the co-called carbonization process alluded to in my notes on Mr. Maclay's paper, before referred to, might be attributed to the moderately high temperature necessary, in this process, to produce a highly charged hydrometric atmosphere in the carbonizing chamber?

Resuming the endeavor to determine whether the apparent peripheric strength really existed, I reasoned that this would be shown by testing briquettes of large peripheric dimensions inclosing greatly reduced areas. This was accomplished by inserting a core longitudinally through the centre of the larger circular briquette before mentioned, and the area of this core section was one-half of one square inch, thus producing a hollow briquette similar to that shown in the following sectional sketch, having a peripheric measurement inside and out 50 per cent. greater, and an area 25 per cent. less than the solid one of the same exterior dimensions.



Specimens were moulded under like conditions, of both the hollow and solid form, and also of the form of ½ square inch breaking area, kept in water the usual 7 days, and then tested with the following results :

Kind of Briquette.	Length of line bounding the breaking section, inches.	Area of Briquette, square inches.	Strength of Briquette, lbs.	Strength per Square inch, lbs.	Strength per Linear inch, lbs.
Hollow.	7.5	1.5	93.10	62.07	12.41
Solid	5.0	2.0	136.50	68.25	27.30
½ solid.....	2.5	0.5	67.50	135.00	27.00

These determinations indicate, if they indicate anything, that there is no great difference in the absolute strength of different portions of the mass subjected to water exposures for the time stated.

Cannot this anomaly of apparent peripheric strength be explained satisfactorily? It is known that mortars, like all other brittle substances, possess elasticity. In tensile tests the application of stress through the clutch is at the surface of the specimens.

The greater the elasticity of the substance under test, the more uniformly will the strains be distributed throughout the mass of the breaking section, but in brittle substances, like that we are now considering, the elastic limit is reached at the surface while great inequality of strain exists throughout the mass. Rupture must first occur at the surface, at once reducing the area to the limit at which complete separation takes place.

Tests of abrasion, or of impact, might have been resorted to in making this inquiry, but these methods afford no means of determining absolute tensile strength in pounds per square or linear unit of measure.

In conclusion, I desire to express my deduction by formula, the correctness of which I leave for further experiments and other experimenters to verify or disprove, when applied to briquettes varying in rupturing area from ½ to 4 square inches, and not exceeding the age stated in this paper.

Let P represent the periphery of breaking section of known strength, S per square unit. The strength S' per square unit of a briquette of similar form and material having a periphery P' will be

$$S' = \frac{P\,S}{P'}$$

However repugnant this may be to our usual practice, the logic of fact must govern in the end.

Discussion at the Twelfth Annual Convention upon the above paper No. CCIII., Tensile Tests of Cement, by D. J. Whittemore, and also upon Paper CXCVII., American Natural Cement, by F. O. Norton, Vol. IX., p. 278 July, 1880.

William P. Shinn.—I regard this subject of the tests of cement as one that has heretofore received but very little attention from the profession compared with its importance. The experiments of Mr. Whittemore are certainly of very great interest. I deduce from his paper that he has made no comparison of the comparative strength of briquettes of different sizes per square inch of breaking section for long periods of exposure, longer than seven days to forty, as I understood it, and it would be very interesting to know whether the same rule holds good for long periods of exposure, say from six to twelve months.

D. J. Whittemore.—My own tests extend to seven days. Grant's which are corroborative of mine, extend, one series, to seven days, and the other to thirty days, and the thirty days shows almost precisely the same as the seven days. We have no experiments of any experimenter within my knowledge, extending beyond that length of time.

M. Coryell.—There is one remark made by the gentleman, in his paper, stating that under atmospheric pressure the cement hardens very much. Many years ago I was connected with Mr. A. Welch in building the Chesapeake and Delaware locks, and he ordered certain specimens of cement to be tested. I did test those cements according to his direction, and I had to report to him that they would not come up to his requirements. The circumstances were such that we had to force the locks along, and we had to use the cement as we could get it, and the locks were completed and finished. But for some cause or other we had to take up a portion of the floor and examine the cement, and I reported to him that the cement was not at all satisfactory; still we had done the best we could. After a long while, and when the locks were about to go into use, Mr. Welch requested me to examine the locks at all these points that I thought might be weak and defective, to see whether the cement had hardened properly. I did so, and I had the satisfaction of finding that the cement had increased in hardness very much by being taken

from the exposure to the atmosphere and covered with water some six or eight inches deep, and all the tests I made in that lock bottom were found to be satisfactory. The cement assumed all the properties that it was intended to assume, and we have never heard of any disturbance or break in it since the completion of those locks.

ASHBEL WELCH.—I think it is very desirable that these experiments should be extended over long periods of time. We all remember in our experience, probably, occasions where cement has been rejected, where it did not stand the test, where after a few days it was found entirely unsatisfactory, and I remember one case where a cement barrel was tested and found to be defective, and it was tumbled into the river. We had occasion afterwards to remove that—some months afterwards—and the best way to remove it was found to be to blast it.

JAMES B. FRANCIS.—There is one other important matter in connection with this, and that is the temperature of the water with which it is mixed. It has great effect on the early hardening of the cement—the temperature of the water. Mixed with water of 32° it may be two or three days before it is at all hard; mixed with water of 70° or 80°, in a few hours it will be thoroughly set; and it seems to me that this is an important matter to be taken into account.

D. J. WHITTEMORE.—It was 66 degrees Fahrenheit; it didn't vary a degree except in the sealed jars; there it stood at the normal temperature of the room.

ASHBEL WELCH.—If you will allow me a moment to travel out of the record, I would mention that American cements were discovered about sixty years ago, by Mr. Canvass White. He was sent over by the State of New York, when they were about building the Erie Canal, to make provision for cement in England. He found there were two difficulties about getting and using that cement. In the first place, it was very dear. In the second place, after they got it here, after being six weeks on the ocean, they found that it was good for nothing. That put Mr. White upon his ingenuity, and at Chittenango, in western New York, he found or judged that cement rock consisted of a mixture of slate and lime-stone, and where these two formations met together he conjectured that the mixture might be hydraulic. He examined it and found it so, and that was the beginning of the history of American cement. The State of New York gave him $10,000 for his discovery.

JAMES B. EADS.—Before dismissing the present discussion, I

would suggest that there are few materials that are tested by engineers which give such a wide range of strength as cements. In my own experience, I have been struck with this great range. It is very different from that which we have in steel, iron and other materials, wood, stone, etc. But there is a degree of elasticity in the hardened cement which Mr. Whittemore speaks of as being a brittle material, that possibly may explain the phenomena of so much greater strength being developed by the small briquettes than the large ones. Cement admits of very considerable expansion before fracture, and very considerable shortening under pressure. I had occasion to make tests to determine this matter in connection with the St. Louis bridge, and some very curious results were developed by it. Among the materials found very much more elastic than originally supposed to be, was stone. For instance, we had a small column of stone, about an inch in diameter, magnesian lime-stone, and it shortened about a quarter of an inch. It was ten inches in length, and it shortened nearly a quarter of an inch under compression without fracture. Cement is much more elastic, and in that elasticity may be discovered the secret of this curious phenomenon of the greater strength of the small briquettes. If we apply the scientific uses of the imagination to the subject, and suppose that a briquette under test be only partially solid, and enlarged at each end, and undertake to extend it, we find a depression at each end showing that the interior particles are not strained to the extent which the surface is, and as the area increases with the square of the diameter, while the part which first feels the impulse of the tension only increases with the diameter, we see at once that the larger the briquette, the smaller would be the strength developed in the tests. I would add that I think the same phenomena would be found in testing iron and steel.

William P. Shinn.—It is to a certain extent.

James B. Eads.—The larger the sample under test, the smaller would be the strength per square inch.

James B. Francis.—As Portland cement has been referred to here frequently, I think it may be interesting to state that last summer I visited one of the large establishments where it is made, and perhaps a few minutes explanation in regard to it may interest some of the members present. It is made out of the material found on the spot. This establishment that I visited was on the bank of the Thames, a few miles below London, at North Fleet, where they are making a hundred or more

tons per day. The material is chalk found in a hill close by, and mud found in the river directly in front or near by, which was dredged out of the river as being the cheapest place to get it. That is all the material that is used except fuel, nothing else whatever. These are mixed in proper proportions which are got at by frequent testings in the way mentioned here, and the excellence of the cement depends on the completeness of the manipulation and close watching of the preparation. The first process, as I recollect, was a rough mixing of a proper quantity of chalk and clay, which were measured out in measures of a certain quantity of clay and a certain quantity of chalk, and ground very roughly, and after that passed through a stone like a grist mill, and the material was then allowed to settle and dry, with the waste from the kiln in which the material was afterwards burned. It was then cut into lumps and put in this kiln, with the fuel which consisted of waste small coal from the gas works, and burned at a very high temperature, so that in looking under the kiln I could see the melted material, where there was a little excessive heat, run off. It was at as high a temperature as they could burn it without melting. After the fuel was all burned out, the material in the kiln was taken out and broken in a Blake crusher, and was then ground in a mill stone, like a common stone, such as the millers use, and that was the end of the process. It was then packed in barrels or boxes and was transported. The price at the works was about $7 per ton of 2 240 pounds. It seems to be a very remarkable result to obtain from such simple materials in that way.

J. H. Harlow.—The main points of the paper which has been read have been in regard to using the tensile strain as the only requisite necessary in buying cement. Now they should use the others—the fineness and the activity—the fineness, because the finer the cement the more perfect the mixture would be with the sand added to it; and the activity, because the cement that cannot be used on this first set, is not as strong on the second as on the first. I made an experiment at the Government works at Pittsburgh, on the second sets of cement, and I found with one exception (a Portland cement manufactured near Pittsburgh), that they were from 50 to 75 per cent. weaker than on the first; that one special cement retained its strength. We had another cement there that we tested, and its activity was so quick in setting that at the end of ten minutes it was strong as most of the other cements at the end of 24 hours, while at the end of three months the strength of this particular cement

was only as strong as the others setting slower ; at the end of six months the slow setting cements were 50 per cent. stronger than the quick setting cement, and judging by all we observed on the stone work built there at the end of two or three years, this cement was just about as good as mud.

MAX E. SCHMIDT.—I would like to ask Mr. Norton whether he made any tests of transverse strength in cements, and compared them that far.

F. O. NORTON.—No.

MAX E. SCHMIDT.—These tests were made lately, and it was found that the foreign brand showed very much higher than the American brands tested. There were eight inches between supports, and the result was for the foreign brands about 40 pounds per square inch of transverse strength, while the American brands did not give over 20.

F. O. NORTON.—At what age were they broken ?

MAX E. SCHMIDT.—Seven days.

F. O. NORTON.—Seven days of Portland cement will show from three to five times as great strength as American cement. At seven days Portland cement has two-thirds of its maximum strength. Those curves (pointing to the diagram upon exhibition), are all carried along for a year, showing the ultimate strength of the two cements.

MAX. E. SCHMIDT.—The strength of the home brands was increased by having them immersed in water later than the foreign brands ; keeping them out 24 hours and then immersing them, and in that manner getting 50 per cent increased transverse strength.

E. S. CHESBROUGH.—I would like to make one suggestion to the Society. We have heard of a great many experiments with different kinds of cement, English and American. About twenty-five years ago I made a good many experiments by mixing different kinds of American cement, and, although the results generally were not satisfactory, and there was no improvement, it happened in one case that the best cement when mixed alone was not so good as when mixed with another cement that was rejected entirely and considered good for nothing. But the two mixed together made a better cement than the one which was better than all the others used alone. I regret very much that we did not at the time preserve an analysis and accurate records of the tests, but I simply throw out that suggestion to members of the Society to say if they have not tried it they may possibly obtain valuable results by mixing the cements of different kinds, and experiments of that sort. The

resulting cement that we obtained was really better than some of our lime-stone in hardness, after it had been kept some time, but at the great fire in Chicago the samples were all lost. As a matter of interest in this connection I will say that the inferior cement which had been rejected was supplied for a time, but in consequence of the carelessness of the manufacturer in letting the standard of it fall below what it was at first we finally had to reject it altogether, as it then proved to be an injury instead of a benefit.

D. J. Whittemore.—I have made cement from twelve different layers of the cement ledge, and then any mixture I might make of those layers was an improvement over any individual layer used in the mixture. I am very careful that cement for any critical purpose should be thoroughly mixed. As far as the tests of Grant are referred to, it should be borne in mind that his tests are made on 1½ inches square, while Mr. Norton's, I understand, are on 1 inch square.

John Bogart.—In the comparisons presented the tests are reduced to the same area; Grant's were on 1½ inches square; Mr. Norton's are actually 1 inch—these tables are for 1 inch.

D. J. Whittemore.—And the variation if the rule holds good that I I have shown in my paper, would be as 4 is to 6. Mr. Grant has made tests with the Roman cement of England up to a period of five years, according to his last report, and he has extended his experiments with Portland to 7 or 10 years, perhaps. The Portland reaches its ultimate strength at about two years. The Roman cements of England continue to improve, as his showing makes it, up to a period of five years; or, as near as I can calculate or formulate it, the Portland improves at a ratio proportional to from the 8th to the 12th root of its age, and the Roman from the 4th to the 5th root, and the exhibit indicates that the American hydraulic cement indurates very much as the Roman cement of England does.

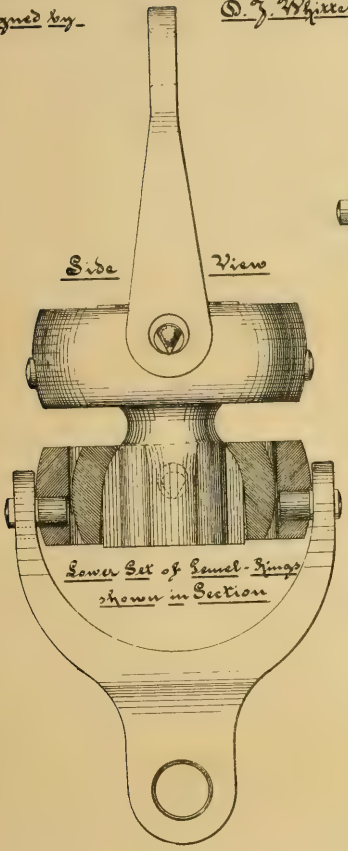
William R. Hutton.—I would ask Mr. Chesbrough if the two cements he mixed were both of the same degree of hydraulic activity?

E. S. Chesbrough.—They were not; one is what is called Clark's La Salle Cement of Illinois; the other was called at that time the Sandusky Cement of Sandusky. It had very little activity indeed; it was so inferior that it had ceased almost to be of value at that time; but the manufacturers, when they found it was adapted for mixing, were so elated with it that they became careless, and sent in a still more inferior

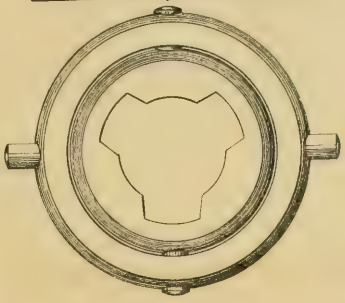
Briquette and Pinbal Clutch for Ascertaining Tensile Strength of Cements

Full Size.

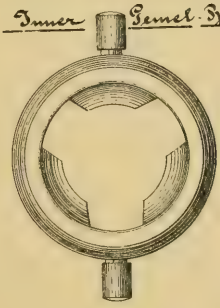
Designed by O. J. Whittemore, C.E.



Bottom View of Gemel-Rings.



Top View of Inner Gemel Ring.



Plan of Briquette.

Briquette in Perspective.

Side Elevation of Briquette

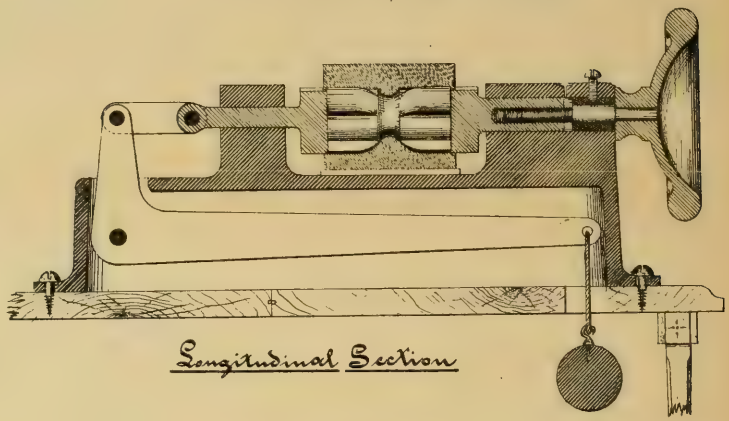
PLATE XVII
INSTN. OF CIVIL ENGRS.
MINUTES OF PROCEEDINGS VOL. LXXIII

Press and Flask

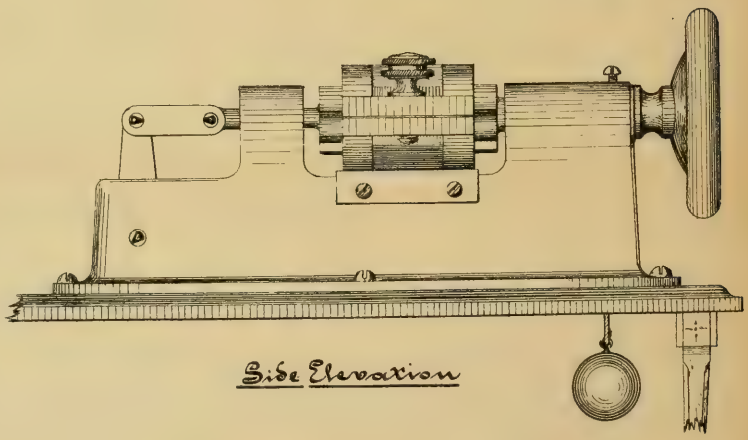
for

Molding Briquette

Designed by D. J. Whittemore, C.E.



Longitudinal Section



Side Elevation

Scale = Half Size

PLATE XVIII.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. IX. No. CCIII.
WHITTEMORE ON TENSILE TESTS OF CEMENT.

article, so finally we had to reject it altogether. But I will say that we never had in Chicago a better cement than we obtained from that mixture as long as the two cements were sent in good quality.

William R. Hutton.—I have used very quick setting cement from the Potomac, a yellow cement. It set too quickly, and we mixed it with Rosendale, the object being to make it set more slowly, and we made an excellent cement. We had no tests, but it worked smoothly, and good results followed. In the one case we had a very quick setting cement, which set in three or four minutes, but mixed with the Rosendale of the ordinary quality that we had, it set in about half an hour, with very good result.

F. O. Norton.—The Rosendale ledges or quarries are of different strata, and they vary from the quick setting cement like the Potomac to cement that takes an hour and a half to set. They vary all the way from 3 minutes in setting, to an hour and a half. There are some thirty different strata in the Rosendale formations, and I think from a combination of all these different strata we get the best results. The quarries are capable of producing almost any kind, either quick or slow setting cement, and it is found very economical to work them all together, and they are usually worked in that way. Ordinary quick setting or ordinary setting Rosendale cement, should set in a mixture with sand in about three-fourths of an hour. Neat, it will set in half that time. But from the first mixture, in general use, it takes about three-quarters of an hour for the cement mortar to fairly set.

D. J. Whittemore—It is very satisfactory to know that cement of the excellence shown by Mr. Norton's statistics can be produced in this country. That this is so, I feel is largely due to his individual efforts.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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CCIV.

Vol. IX— September, 1880.

WATER-PROOF COVERINGS.

By F. COLLINGWOOD, Member of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, MAY 25, 1880.

With discussion by EDWARD P. NORTH, and an additional note by F. COLLINGWOOD.

As a contribution to the general subject of the use of asphaltes, bitumens, &c., the writer would offer the following bit of experience:

As it is intended that the arches of the approaches of the East River Bridge shall be used for mercantile purposes, it became necessary to cover the concrete over the arches with some protecting substance, which should keep out all dampness from the masonry. On inquiry among persons engaged in such work, a great diversity of material was offered, and each urged as the best for the purpose.

It was accordingly decided to ask bids generally, each bid to be accompanied by samples for testing.

In deciding on the tests, the following requirements were had in view:

1*st*. That the covering should be impermeable to water at all temperatures, and

2*d*. That it should be permanent.

It is evident that there is little danger of failure at high temperatures, but at low temperatures, cracks may develop from contraction or shocks, allowing water to pass through. The tests on this point were, to make some wooden moulds with grooves about 2 feet long, with enlargements at the ends, so as to give a shape like an eye bar, and fill them with the mixture. These, with some flat plates of the material, were exposed to a freezing mixture for 48 hours. Some of the long pieces cracked under this test. After freezing, the plates were first tested with a loaded point for penetration, and then dropped a short distance to see whether they would break. In this way a fair idea of the respective hardness and brittleness was obtained, and also (by careful measurements), the relative contraction.

After this the specimens were exposed to heat, to see their behavior under a high temperature.

The next tests were for durability; and proceeded upon the assumption that in process of time, destruction must occur, if at all, in two ways:

1*st*. By the gradual evaporation at ordinary temperatures of the volatile oils contained in the water-proofing material, and which give plasticity to the mass, thus causing them to be crumbly and absorbent, as witnessed in coal tar roofs. The test for this was to weigh with delicate scales a small mass of the material, and expose it in a sand bath, to a temperature of 212° for 48 hours, noting the percentage of loss.

The *second* possible cause of failure, was considered to be absorption of water, which by freezing and thawing would eventually cause disintegration.

For this test, carefully weighed specimens were soaked in water for 48 hours, taken out, wiped carefully, and reweighed to determine increase in weight.

A third possible cause of deterioration would be looseness of structure, causing rapid abrasion under passing loads, but this would be determined by the second test above.

The various samples offered may be classified as follows:

1*st*. Alternate layers of coal tar and felt.

2*d*. A mixture of soapstone, crude petroleum and resin.

3*d*. Trinidad bitumen (refined) and coal tar, with an admixture of sand.

4*th*. Asphaltic mastics consisting of various mixtures of Val de Travers or Limmer asphaltes, with Trinidad bitumen, residuum oil, limestone, sand, &c.

5*th*. Trinidad bitumen, with paper or felt, in consecutive layers.

6*th*. Trinidad bitumen (refined), mixed with about 10 per cent. of residuum oil, put on in consecutive layers.

The tests showed that all of No. 1 were totally unreliable for permanent work.

No. 2. Is an admirable fire proof material for roofs. There was a loss of one-half per cent. by boiling, however, and the price was too great.

No. 3. Absorbed 3 per cent. of water, and was evidently poorly prepared.

No. 4. Of these the best samples were excellent, but were rather hard at low temperatures. Of the poorer ones (those most adulterated), some failed by cracking, showing brittleness, others by absorption, taking up as much as 4½ per cent. of water. The best were too expensive.

No. 5. Were decided against, on the ground that no paper layers could be made continuous, and there seemed no reason for inserting a foreign substance which has no protective power of its own.

No. 6. A mixture of 20 per cent. residuum oil and 80 per cent. Trinidad bitumen was found to be too soft. The residuum oil or petroleum wax, is that product of the distillation of petroleum which passes over at temperatures between 800° and 900° Fahr. Reducing the oil to 10 per cent. gave a mixture neither too soft when warm, nor too brittle when cold, entirely non-absorbent, and losing nothing when boiled. It was therefore decided that as the price was less than that of any other acceptable sample offered, the bid would be accepted, to put down three layers having a total average thickness of half an inch.

The lesson to be learned from these tests in respect to the use of such materials in road making is this, that it is possible to take a piece of material from a street (a very small piece will do if chemist's scales are used), and determine at once whether there is a reasonable probability of its being of a lasting character. All experience goes to show that compressed asphalte cannot be durable unless well compressed; and the absorption test ought to reveal the physical condition of any specimen as to porosity. A tensile test, by comparison with known mixtures,

would reveal something also as to adulteration of the mixture by an excess of grit or earthy material. One bidder put in peat for some purpose best known to himself. Of course, no person would recommend the mixture adopted as suitable for road making, it can only be used where covered from the sun's rays by an external covering of some thickness, for the express purpose of keeping out water.

This experience is given as one method,—in the present case a very successful one,—of deciding among a lot of bids having apparently few points in common on which to base a decision.

Edward P. North.—The interesting experiments detailed by Mr. Collingwood, may be supplemented by a notice of the tensile strength of some samples of asphaltic mastic (No. 4, mentioned above), and of a bituminous mastic known as Filbert's vulcanite.

The asphaltic mastic was made from Val de Travers asphalte, melted in the ordinary refined Trinidad bitumen, with the addition of about 50 per cent. of clean silicious grit of the size of a pea.

The vulcanite is identical with that tried in Fifth avenue, between Twenty-fourth and Twenty-fifth streets, in August 1879, and is composed of 14½ gallons of refined Trinidad bitumen, 7 cubic feet of fine sand, both heated to 300° F., and 1 to 1½ gallons of a mixture of cement, limestone dust and sulphur, all mixed in a horizontal pug mill.

The test pieces were one inch square, and were broken on a cement testing machine that only registered to 400 pounds.

Four samples of the vulcanite were broken at 120, 140, 185 and 230 pounds. Five samples of the asphalt mastic were broken, one at 352 and one at 400 pounds, the other three stood 400 pounds for over a minute and broke with an added weight of from 20 to 50 pounds. All the test pieces were immersed for over an hour before breaking in ice-water; the temperature of the room was 85°.

The asphaltic mastic probably had more than twice the tensile strength of the vulcanite, and would be less liable to crack from changes of temperature.

This mastic, without the addition of grit, is largely used in France for covering arches, casemates and powder magazines, with very satisfactory results, as the mastic yields to the settlement of the masonry without cracking.

It may be doubted if the test proposed by Mr. Collingwood would be a valuable aid in selecting a paving material, as newly laid com-

pressed asphalte would not show as well under it as the mastic, yet experience has shown that it is much more durable than the latter for wheelways, so much so that the Limmer Company, of London, are replacing their mastic pavements with compressed Sicilian asphalte, and it is doubtful if asphaltic mastic will wear better than the best of the bituminous mastics as now laid, particularly under rapid traffic in cold weather, but the asphaltic mastic would be the best absorbent of the two.

F. Collingwood.—In continuation of the discussion on "waterproof coverings," I have a few additional facts to offer.

Our work, as far as it was concreted, was covered during cold weather with the mixture mentioned above, viz., refined Trinidad bitumen with 10 per cent. of residuum oil. It was then expected that the stone paving would be laid early in the spring, and a thick layer of sand was spread over it. Instead of this, owing to delays, the pavement has not yet been laid (July 24th, 1880), and the whole has been exposed to the hot weather of the past few months.

The temperature has, under the circumstances, been sufficiently high to cause the bitumen to rise in places through the sand, and to flow to a moderate extent.

This experience shows that it is necessary to attend to the upper limit of temperature as well as the lower. I am now inclined to think that the bitumen would be better without any oil. With the full thickness of paving and sand we expect to put above it, the temperature will probably not be high enough to disturb it. This is, no doubt, the reason for the introduction of felt and paper in its use over roofs and sidewalk vaults.

There is a practical difficulty in applying it to the inside of drains. When hot enough to insure thorough adhesion to the walls of the drain, the smoke is so thick that the workmen cannot see what they are doing. The soap solution would probably be the best application in such locations.

The asphaltic mastic without grit is unquestionably a good material, as a number of such samples when tested, showed no absorption.

This would have been selected in the case of the bridge work, had not the price been higher than that of the bitumen. It was not considered enough better to warrant paying the considerable difference there was in the bids.

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(Vol. IX.—September, 1880.)

DISCUSSION

By DE VOLSON WOOD, MEMBER OF THE SOCIETY, ON THE RESISTANCE OF BEAMS.*

The main object of this paper appears to be to set forth a new theory of the resistance of beams; or perhaps, more strictly speaking, to explain in a new way the discrepancy which exists between the common theory and the results of experiment. (See §§ 24–32 of Emery's paper.) In order to show that more theorizing is needed, that writer has given an abstract of what is known upon the subject, together with the views of certain theorists; and these show not only that a discrepancy exists, but also that theorists are not agreed as to its cause. A critical study of the problem has baffled the efforts of every student who has attempted its solution; and yet the only condition required by theorists, in order to establish a correct formula, is to know *the law of action* of the internal forces in the section of rupture. The determination of this law is, therefore, the direct object of our study. Within the elastic limits the law is sufficiently well known, but that limit must be greatly exceeded before rupture can take place, and beyond that limit the law is different for different materials, and is by no means consistent for any class of materials.

It seems natural to assume that the law of extensions and compressions would be the same in a beam, as in a prism of the same material subject to a direct pull or push. Mr. Emery has subjected this hy-

*Flexure and Transverse Resistance of Beams: C. E. Emery, Vol. VIII., p. 149. June, 1879.

pothesis to the test of experiment, and the work done being important (and I think original), I wish to bring forward two of his results. Experiments were made upon of a specimen material like that in the beam, and a curve constructed to represent the relation between the stress and strain to the point bordering on rupture. This was called *the experimental curve.* In § 17 he finds in one case that the modulus of stress on a unit of outer fibres, when the actual experimental curve was assumed to express the law of action of the internal forces, should be 29 027 lbs., whereas the actual ultimate tensile strength of the metal (cast iron) was 15 458 lbs., or about one-half that found above.

In another case, given in § 19, the experimental curve hypothesis gave 17 941 lbs., while the ultimate actual strength of the metal (gun metal) was 25 647 lbs., or nearly 50 per cent. more than that given above.

These results were a surprise, for we had long felt confident that this mode of treating the problem would give results at least approximately correct. It is true, as shown by Mr. Emery, that it is difficult, if not impossible, to obtain the true experimental curve at the point bordering on rupture; also that an empyrical equation was used to represent the curve. The curve is also modified by the manner of making the experiments; for if determined by repeated pulls, whether accompanied by shocks or not, it would be very different from that determined by a steady, continuous pull. We are, however, confident that in a large range of experiments, many cases would be found which would not only agree more nearly with experiment, but would, in those cases, give better results than by the common theory; still, if the examples given by Mr. Emery are not exceptional in their character, it appears that, in many cases at least, the experimental curve hypothesis is, theoretically, but little, if any, better than the common theory, and must be abandoned as practically useless. Even if it gave satisfactory results, the difficulty of using it is so great, that it would not be employed in ordinary practice, but would be confined to theoretical investigations.

Having shown the failure of this hypothesis, Mr. Emery gives his new theory in the following words (§ 25): "It is suggested as highly probable, in fact, almost a necessary inference, that on account of the lateral adhesion of the particles, the strains of greater intensity near the top and bottom, and at the centre of the beam, are in part transferred to the lamina of less strain in the direction of the curve nearer the axis, so

that the fibres crossing the central section of maximum moment are under greater strain than their proportional distance from the axis, and the outer fibres thereby correspondingly relieved." The "curve" here referred to is the isodynamic curve (or curve of equal stress); but I am uncertain as to the precise meaning of the expression "in the direction of the curve," but there is no doubt as to the general meaning—that fibres nearer the centre sustain more than their proportional part.

In regard to this hypothesis we need only say, that, if true, *the law of its action* is not given, and hence, new formulas cannot be founded upon it, nor the existing formulas modified so as to conform with it. But aside from this, it appears to us that the action (if any) due to the form of the curves of equal stress is quite too small to account for the great discrepancy which is known to exist. Until the law of action is given, very little can be said in regard to the hypothesis.

But we will make a remark in regard to the isodynamic curves. Their equation is (see (60):

$$Mk^n = \frac{Yb \cdot h^2}{1+n}$$

in which M is the moment of external forces, k the ordinate to the curve from the neutral axis, b the breadth of the beam, h its depth from the neutral axis, and n a constant depending upon the equation of the experimented curve, which equation is $y = ax^n$. In the equation of the curve if $M = o$, $k = \infty$; and if $k = o$, $M = \infty$; hence the curves are asymptotic, the vertical, through the origin being one asymptote, and the axis of the beam the other. If the beam be supported at its ends and loaded at the middle, the moment of the load will be $\frac{1}{4} P.x$ (P being the load and x the abscissa), and also if $n = 1$ as in the common theory, the equation of the curves becomes

$$Pxk = Yb \cdot h^2$$

and hence, they will be equilateral hyperbolas; the curves from the opposite ends meeting at an angle at the center of the beam.

Mr. Emery remarks (§ 27), that "from this it appears that the increased strains due to the diagonal action of the curves, may become so important that the fibres will part at one side of the section of maximum moment as is frequently reported." The questions naturally arise—if such is the result in one case, why not in all cases; and if not in all cases, what conditions determine when it will and when not break at that point? It will be observed that the lines of equal stress are de-

termined according to the common theory, but if the action above referred to is considerable relatively, the curves will thereby be relatively modified ; and thus their equation become unknown.

Again, it is not necessary to resort to the theory of isodynamic curves in order to show that the fibres are not strained proportionally to their distance from the neutral axis. The experimental curves show that after the elastic limit is passed, the elongations are greater in proportion to the pulling force - a fact known long before these results were plotted. Assuming that the stresses are proportional to the ordinates from the neutral axis within the elastic limits, it follows that when that limit is passed at the outer fibres, it will require less force to elongate them proportionally, and hence, for a given increase in the elongation, those not strained to the elastic limit will be subjected to a greater proportional stress. There is no reasonable doubt that this action actually takes place. Here then is one reason why the common theory does not give correct results.

Confirmation of his hypothesis is inferred from the fact that the isodynamic curves resemble the lines of stress in glass, as shown by polarized light (§ 27). But the resemblance is scarcely more striking than that between the same lines and the lines of maximum stress, first deduced by Airy, the Astronomer Royal of England, and published in the transactions of the Royal Society of London. (See also the writer's *Resistance of Materials*, 3d Ed. p. 239). The resemblance, however, is only accidental, for the stress which causes the polarization of light is a shearing stress. The experiment with polarized light confirms the theory entertained by most writers upon shearing stress—that it is greater near the neutral axis, and least (or nothing) at the elements most remote from it ; also, that there is a shear in the vicinity of the pressures—one at each end, and another at the middle. If a beam be supported at its ends, and loaded with equal weights at points equidistant from the ends, that portion of the beam between the loads will be acted upon by a statical couple, and, according to theory, will have no shearing stress. And, generally, any portion of a beam acted upon by a statical couple, produced by any system of loading, will be free of shearing stress. In this case, also, the isodynamic curves will be parallel to the neutral axis. Here is a field in which experiments have not been made, and one which offers an opportunity for testing certain hypotheses in the resistance of materials. Thus, by means of polarized

light, the existence of a shearing stress in certain solids can be determined. If none exists, it can next be ascertained whether the absence of *shear* affects the formula for the strength of beams. According to theory, a beam, in such a condition, is equally liable to break at any section between the equal loads, and if it should break a greater number of times at one point than another, a search for the cause might result in a modification of theory.

In § 32 it is stated: "Evidently for solid beams the equalization of strain referred to must commence as soon as flexure begins, which explains the fact that the ordinary formulæ are incorrect, even within the limits of elasticity." This statement does not appear so evident to us. Whatever be the direction of action of the forces at the several points in the section of rupture, they can all be resolved into horizontal and transverse components; the former of which tend directly to pull or push the elements, and the latter, to pull or push them transversely. The former gives rise to the ordinary formula, and the latter to a modification of that formula on account of the deflection induced by the shear. Beyond this we see no ground for equalization within the elastic limits; unless we consider the infinitesimal change due to a change of form of the transverse section, a quantity far too small to be measured directly.

It will be observed that the form of the isodynamic curves is independent of the character of the material; but, if there is anything important in Mr. Emery's hypothesis, the action, due to their existence, must be greatly modified by such character. Thus, in many kinds of timber, the fibres are so well defined that a transverse action has a very different effect from a direct pull, and the same is true, though in a much less degree, with wrought iron; but cast iron is so nearly granular (or amorphous), that a force would produce nearly the same effect in any direction; and yet, strange as it may appear, in the last named substance, in which the elements are the most free to adjust themselves, the greatest discrepancy exists between theory and practice, in the case of beams.

Barlow's theory, combined with the common theory, gave results which agreed more nearly with experiment than any theory heretofore given; but its principles, as stated by its author, are so much at variance with those held by the most eminent writers that it had to be abandoned. For instance, Barlow stated that the longitudinal shear was caused by the unequal extension (or compression) of the consecutive fibres at dif-

ferent distances from the neutral axis, hence existed in all cases where a beam was bent; but according to the theory of Lamé, it is due to the *unequal* stress at two points of the *same* fibre. This view is supported by the most eminent writers since his day, including such names as Louiville, Weisbach and Rankine; and I think that this view is incontrovertible. According to Barlow's principle, a shear would exist in that part of a beam subjected to a statical couple, while, according to most other writers, no shear exists there. Again, Barlow stated that the shear would be uniformly distributed over the transverse section, because the extension of the fibres increases as their distance from the neutral axis; but, according to the theory of the writers above named, the shear is zero at the outer elements, and increases to the neutral axis, where it is greatest, a result which is confirmed, as before stated, by experiments upon glass with polarized light.

The breaking of materials is, physically speaking, a harsh operation. The materials used in constructions are comparatively gross, and rarely, if ever, break twice alike. This is illustrated by the pulling asunder of cylinders of iron and of steel. If the specimens be made as nearly alike as possible and from the same stock, they will exhibit different tensile strengths, but, fortunately, for such specimens, the difference between the greatest and least values of their absolute strengths is generally only a small fraction of the mean value of their strength. But this lack of uniformity in absolute strengths renders it impossible to make a formula which will agree *exactly* with practice in special cases. Still we do desire a theory which will give results approximately correct.

Just here we will indicate a cause of the discrepancy which has not heretofore, that we are aware of, been considered. Theory assumes that breakage takes place in a plane section, but this condition is never realized in practice. Is it not probable that if the entire surface in the section of rupture and the actual position of the neutral axis at the instant of rupture be used in the ordinary formula, the result would agree more nearly with experiment? Still further, if the "experimental curve" of extensions and compressions be also involved, would not the conditions give results which would agree as nearly with experiment as could reasonably be expected? Should it be found that these conditions would account for the recognized discrepancy, it would be of but little practical use, for one of the conditions, if not two of them, could not be accurately determined until after the beam was broken, and

the other would require an independent experiment with each piece to determine the experimental curve; still it would serve one good purpose—that of showing where the cause of the discrepancy lies, and thus remove the grounds for further theorizing on this point. Several considerations, founded upon past experience, may be made to bear upon this view of the subject at once. Thus, timber, for instance, in the ruptured section presents a splintered form, and in most cases it would be practically impossible to determine the actual area of rupture. In some cases wrought iron exhibits very clearly its fibrous character, not so much in the splintered appearance as in its separating in layers. In these kinds of materials, when the extreme fibres rupture at a point other than that at that of the maximum moment, may there not be a shearing between these fibres and those next to them not yet broken, which will aid materially in sustaining the load. In the rupture of cast iron and of steel there is no fibrous appearance, and it is not so plain how longitudinal shearing can act to resist breaking. If the principle which I have suggested above –that of considering the entire section of rupture—be the correct one to use in practice, it would seem, at first sight, as if fibrous bodies ought to give a greater discrepancy between theory and experiment than granular ones; but we are unable to say what accurate measurements would show. In the case of timber, if any part of the area of rupture consisted of the surface between fibres, that part should not be entered in the ordinary formula, for the stress on that surface would be a shear, and the modulus for shearing in timber is very small compared with the tenacity, in some cases being as low as $\frac{1}{10}$th the tenacity.

These suggestions show that there is still a field open for experiment, and until every question which is raised in regard to the rupture of beams is investigated, both theoretically and practically, should we despair of accounting, in a satisfactory manner, for the present discrepancy between theory and experiment.

This seems to be an appropriate place for giving a summary of what is supposed to be known in regard to this subject.

In a prismatic beam fixed horizontally at one end and broken by a load acting vertically at the free end, or such a beam supported at its ends on horizontal props and broken by a load at the middle point, we are supposed to know the following facts in regard to the action of the internal forces :

1. On the convex side the longitudinal elements (called fibres) are extended, and on the concave side compressed.

2. There are elements within the beam which are neither extended nor compressed, and the surface which contains these elements is called *the neutral surface.* Theoretically, this surface is assumed to be cylindrical, the elements of which are transverse to the beam ; but in the solid it is probably very irregular, due to the non-homogeneous character of the material. This surface is not free from stress, for if it were, the same action would be secured by two beams of the same breadth and length but of half the depth, placed one upon the other ; but it is well known that the action will be very different from what it would be with two such beams. The stress on the neutral surface is called *a shear.*

3. Whatever be the law of action of the stresses, the sum of all the compressive forces upon the fibres will equal the sum of all the pulling forces. This is merely putting in formal language one of the principles of Statics—that the sum of the axial components of all the forces will be zero for equilibrium. Since the forces act normal to the axis of the beam, they will have no component parallel to that axis, hence the algebraic sum of the stresses must be zero. This principle was correctly stated by Coulomb more than a century ago, but more recently two eminent writers, Navier and Barlow, both for a time used instead thereof the erroneous principle that the sum of the moments of the stresses in reference to the neutral axis was equal to zero. The principle enables one to determine the position of the neutral axis when the law of the stresses is known ; and if the extensions and compressions are proportional to the stresses the neutral axis will pass through the centre of gravity of the sections, as shown by Navier about the year 1824. It also follows that if this law changes, as it does after the elastic limit is passed, the neutral axis may change, and in practice will move towards the compressed, or concave, side. The principle here stated is also very nearly true if the section of rupture be irregular, and it would be exactly true if the fibres were horizontal at the points of rupture, and the moment of the longitudinal shear be disregarded.

4. Whatever be the law of action of the forces for the beams here under consideration, the sum of the moments of the stresses on either side of the section of rupture will equal the sum of the moments of the breaking forces on the same side of the section. This is true, whether the section of rupture be plain or irregular; for it is simply a

formal statement of one of the general formulas of Statics that the sum of the moments of all the forces acting upon a body is zero for equilibrium. It is also independent of the position of the neutral axis. The difficulty of applying this principle correctly in practice consists in determining the stresses at different points of the section of rupture. They depend for their value upon the position of the neutral axis and their law of action.

5. There is a shearing stress at all parts of a beam not acted upon by a statical couple. This is shown by theory, and confirmed by experiment. There is, then, in the beams which we are considering, a shearing stress in all the transverse sections from end to end. A simple resolution of forces shows that there will be a transverse shear equal to the algebraic sum of the external forces between the section to the end—and, hence, in the beams we are considering equal to the forces at the end of the beam; and, according to the theory of shearing stresses, the longitudinal shear at every point of the beam will equal the transverse shearing at the same point. This is true for amorphous bodies, but the law may be modified for fibrous and heterogenous substances. The law of distribution of this stress remains to be determined; but for rectangular beams it is comparatively simple, being nothing at the outer elements on the concave and convex sides, and increasing at a uniform rate to the axis, where it is a maximum. On account of this stress the transverse sections of perfectly amorphous bodies will not remain plane during flexure, even within the elastic limits; but the deviation therefrom due to this cause will be so slight that it could be detected in an experiment only by extremely delicate measurements. The effect of the transverse shearing on the deflection of a beam can be computed, but the effect of the longitudinal shearing upon the ultimate strength is not definitely known.

6. If T be the modulus of tenacity of the material as determined by a direct pull, C the modulus of crushing determined by a direct push, R the modulus of rupture as determined from the ordinary formula ($\frac{1}{4} P l = \frac{1}{6} R b d^2$ for a beam supported at its ends and loaded at the middle), then it is found that R does not equal T nor C, but differs so much from both that we infer that there must be an error in the theory upon which the ordinary formula is founded. In nearly every case if $T > C$ then $R > C$ and $< T$, and if $T < C$, then $R < C$ and T; or in other words, the value of R is between those of T and C for the same material.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

Vol. IX.—September, 1880.

DISCUSSION

BY ROBERT BRIGGS, MEMBER OF THE SOCIETY, ON THE VARIATION DUE TO ORTHOGONAL STRAINS IN THE ELASTIC LIMIT IN METALS.*

Mr. Robert Briggs remarked, that while it was impossible to discuss, with any completeness, so thoughtful and elaborate a paper as has just been presented, he still felt able to add some comments bearing upon unnoticed properties of orthogonal strains upon metals, or rather upon wrought-iron. As long since as 1856 to '59, he had become conversant with many facts upon this subject.

At the United States Capitol and Washington Aqueduct, then under the charge of Lieut. (now Maj.-Gen.) Montgomery C. Meigs, as an assistant-engineer, the speaker was an observer and participator in experiments upon the strength of materials to be employed on those works. By the tests of iron then instituted, it was demonstrated that when iron was subjected to gradual and continuous strain under loads exceeding the elastic limit, which for merchantable iron was generally at about 20 000 pounds per square inch, the ultimate strength or point of rupture under tension became elevated materially.

Wrought-iron of average quality, for bars, beams or plates, in directions of the rolling, was found, under progressive tests, when the whole time of effecting the ultimate test was only a few minutes, or such time as was needed to observe the extensions under the increasing strains, to have an average value of from 52 000 to 55 000 pounds per square inch. In such tests the ultimate extension under each load was rarely attained, but there would occur a large elongation nearly at once when any load exceeding the elastic limits and the previous load was applied, after

* Paper CXCI, by ROBERT H. THURSTON. Vol. IX. May, 1880.

which the bar would become apparently at rest. A portion of this elongation was permanent when the excessive tension was relieved and such portion was found to vary in some regard with the length of time during which the test piece had been permitted to rest under subjection to the load, *and the ultimate extension under that load was more closely attained.* It was also definitely established that when each increment of excessive strain (using the words — excessive strain, to express such strains as would produce permanent elongation), was allowed time to produce its effect in maximum *temporary* elongation, and when these strains, thus slowly applied, were carried to the point of rupture, a whole day, or even two or three days, being spent in testing the piece, the ultimate strength would rise to 60 000, or even 70 000 pounds per square inch for iron whose normal (so to speak) ultimate strength would scarcely exceed 50 000 pounds.

The experiments seemed to indicate with much positiveness, that any test which passed the primitive limits of elasticity, materially impaired the strength of the iron to resist a suddenly applied force, or a blow, but unfortunately they were not pursued as fully in this direction of investigation as they should have been. But they went far enough to impress the speaker with a belief in the hypothesis, which belief he has frequently affirmed since that time, that any impairment of the primitive elasticity of iron was a serious impairment of its serviceable strength in rendering it brittle. It is well known to all engineers, that chains, hooks and bolts, in ordinary service, are worked up to the strains of 20 000 pounds per square inch, or to the elastic limit of ordinary iron, and also that especially in the case of chains and hooks, this limit is surpassed frequently, and attendant upon such strains, repeatedly exercised, they become very short and brittle, and numerous instances of similar effect can be traced to a similar cause in general construction in iron. This view would make it appear that the increase of ultimate strength proceeding from an excessive straining elongation of iron bars is illusory, not to say dangerous.

That the experiment of Prof. Thurston should be followed out to the further consideration of possible orthogonal impairment of the material (and the vibrations occasioned by a blow or shock, are decidedly orthogonal stresses) is certain. In point of fact, it may be stated that the ultimate tensile value of iron is somewhere above 110 000 pounds per square inch, and that in accepting lower rates we are simply averaging imperfec-

tions or want of homogeneity in the particular sample under test. The formation of a fibrous condition is a severance of molecular continuity, so far as lateral cohesion is concerned, while it may be the means of bringing into action more numerous particles than would be in direction of the strain, in a bar wherein the crystals were merely entangled in all directions, or wherein only a portion of the perfect crystals have been extended as amina, or as filaments, in the one direction. The stiffening or strengthening of cold rolled shafting, or of drawn wire, would seem to conform to this hypothesis, while the notable increase of brittleness from these operations, is in a degree confirmatory to it. In further experiments in test beyond the limit of elasticity, it would be well to observe whether the specific gravity of the test piece were effected. It is probable that in the readjustments of the particles whereby new strength is added to the material, that the elongation is not attended with proportionate reduction of section. It is believed that this results in hard drawn wire—that it is less dense than soft annealed iron.

One other set of experiments were made at Washington, in 1858, having a bearing on this subject. In an examination into the strength of bolts, it became desirable to test the strength of iron under the combined strains of tension and torsion. Test pieces were placed in the testing machine, which were square in section of the body, and had round collars turned upon them for the places of rupture. By means of the squares there were attached wrenches, to the arms of which weights were applied at the same time that definite tensile strains were brought to bear on the test pieces. The result of these experiments was very positive, that no weakening of iron for tension occurred so long as the torsional strain did not exceed the elastic limit, and that no weakening of iron for torsion occurred so long as the tensional force applied did not pass the same limit, and that the impairment of strength to resist one strain when the other surpassed its limit, was too discordant to follow any law, although some indications showed that the component of the two strains might be assumed between the elastic limit and half the ultimate strength.

These experiments and their results remain with the *archives of Government;* as the charge of the Capitol construction and of the Washington aqueduct passed from the hands of General Meigs before completion, and subsequent engineers failed to come to an appreciation of their value.

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INSTITUTED 1852.

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CCV.

(Vol. IX.—October, 1880.)

THE LOCATION OF THE CHIMBOTE TUNNELS.

By OTHNIEL F. NICHOLS, Member of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, MAY 25TH, 1880.

The Chimbote and Huaraz Railway was projected for the relief of the upper valley of the Santa River; a valley proverbial for the beauty of its scenery, for its mineral and agricultural wealth, and for the healthfulness of its climate.

Raised from 6 000 to 12 000 feet above the sea, this valley is relieved from the intense heat of the coast, while from its eastern boundary, the snow range of the Cordillera, comes an abundant supply of water for the irrigation ever necessary on the western slope of the Peruvian Andes.

In this valley, within a distance of 60 miles, six large towns have grown up with populations which may be placed as follows :

Huaylas	5 000	Caraz	6 500
Yunguay	4 000	Carhuaz	10 000
Huaraz	15 000	Recuay	4 000

The entire population of the valley cannot be less than 70 000 souls. These people have established close intercourse with their neighbors in the more extended valley of the Marañon, but their only intercourse with the capital of the country and with the smaller towns on the coast, is conducted by mule traffic over the high passes of the coast range, for the Santa leaves the valley through a succession of gorges beginning with the Cañon of Pato and ending at Infernillos, thirty miles distant. These gorges rested in undisturbed tranquility till 1873, and to-day it may be said that no living mortal has been through the Cañon of Pato.

A preliminary study for a railway was authorized by the Government in 1864, but was not completed until some years later, when a line was projected beginning at Chimbote Bay, where a harbor of greater safety, if not of easier entrance, could be found than at the old port of Santa.

Traversing, first, the lands of the Chimbote valley—deserted two or three centuries ago for want of water for irrigation—the line enters the valley of the Santa river, which it follows, first, through tiliable land, with here and there a sugar estate, then through the gorges before referred to, ending at Recuay, 265 kilometers (164 miles) from Chimbote. The survey or study was made for a broad gauge road, and the estimate of cost was 38 000 000 soles. For the purposes of this paper I shall consider soles the equivalent of dollars, since this was about their relation at the period of which I write.

The estimated cost was thought too great, and a narrow gauge road was decided upon. The reduction in the estimated cost seems to have been proportioned, judging from the figures, to the reduction in gauge, a method of great simplicity, at least.

The contract for location and construction was let in November, 1871, to Don Enrique Meiggs for about 24 000 000 soles. The specifications were quite liberal, providing for curves of minimum radius of 61 meters (200 feet), and permitting the use of grades of 5 per cent. in the mountain region.

In November, 1873, the track had been laid to the sugar estate of

Suchiman, about 35 miles from Chimbote, and the location had reached the cañon of Huayna Taquilpon. A preliminary location had been made as far as Tunnel No. 4, but no one had been through the cañon at this time, though a mule road was finished through it within three months of the date named.

I have made these general statements as introductory only, and desire to limit the scope of this paper to the location of the tunnels of the first cañon, although I shall give such details pertaining to the construction of these tunnels as came within my own observation prior to September 1875, when the financial embarrassment of the Peruvian Government caused a suspension of the work.

The rocks of the cañon seem to belong to the carboniferous age, though the strata had been greatly distorted and compacted by subsequent changes, and the coal existing occasionally, in veins from three inches to six feet thick, had been debitumenized and changed almost to graphite. The strata generally dip in the direction of the river, at right angles to the mountain chain, and present some of the most remarkable cases of folding and distortion I have ever seen. The process of change seemed almost a recent one, for nature had never healed the scars. Very little rain falls at this elevation of 3 000 feet above the sea; on the mountain sides water was wanting; there was no vegetation; red, yellow and black were the colors of nature. Rock surfaces were only partially smooth from river washing; the general effect was that of unfinished work recently discontinued.

The Santa is a mountain torrent; its average width about 100 feet, its average depth about 6 feet at low water, and more than 20 feet at high water; its fall through the cañon was about one and one-half per cent., its velocity seven or eight miles per hour. While fool-hardy Chileños have swum across it for large rewards, over fifteen men were drowned in it in less than a year of construction, and I never heard of a single rescue where persons had fallen into it.

The cañon may have been a huge cleft or series of clefts in the rocks, the softer or looser portions washed out to some width, the harder portions remained at first as dams, which backed the river up into lakes in which boulders and coarse gravel, brought by a mountain torrent, became sedimentary deposit; these dams removed, or cut through, the sediment remained in the shape of high gravel flats, through which the river had made an open cut ten to twenty feet deep. These flats, sur-

rounded by high rock walls, were the camping grounds of the cañon, the only tracts nearly level, they furnished the only earthwork, and it was the effort to avail ourselves of the easier work on them which gave us in profile a succession of nearly level grades connected by steep grades through the intervening rock cliffs.

The steep river walls, rising from 200 to 400 feet, seemed vertical, and the mountain sides sloped away from the tops of these walls at slopes often quite too steep for earth to stand. I do not wonder that all the district from kilometers 108 to 111 was embraced on the preliminary study in one tunnel of 2 100 meters (6 890 feet) long.

The location of the tunnels in this cañon became particularly interesting from the fact that in no case was it possible to run the centre line over the top of the tunnel. This gave rise to triangulations more or less extended as the circumstances required. In the triangulations we were frequently compelled to cross the river by means of a rope stretched from bank to bank, carrying a common pulley block from which was suspended a rude seat. In getting about from point to point in location, a gang of men, including at least one sailor, was continually employed making roads and paths. The mule road passed over tops of cliffs, and ran down on to the intermediate gravel flats where practicable. For descent into rock clefts and over the face of cliffs, rope ladders were used, one of 50 feet in length by 12 inches wide; another 104 feet in length by 18 inches in width; these could be carried on donkeys to within a few feet of the spot where they were used. A single rope, lashed to a bar driven into the ground or into a crevice in the rocks, served for examination of very steep slopes, and the "Chileno" chainmen would do some very accurate work on smooth rock slopes of 40 degrees inclination, barefooted, with ropes about their waists, the other end being carried as the chainmen moved, by their fellows on the mule road above. In the locality I have particularly in mind, the mule road had been carried for 200 meters (656 feet) along a glassy rock surface, partly in excavation, partly on little walls supported on horizontal timbers which, in turn, rested on iron bolts driven into holes in the face of the rock.

Plate No. XIX. shows that portion of the department which includes the Santa river, together with a general plan of the line through the tunnel district, with corresponding profile; the contours are 5 metres ($16\frac{4}{10}$ feet) apart, vertically. Plate No. XX. gives details of the most important tunnel triangulations and sections across the river at points opposite Tunnels

Nos. 3 and 7. The triangulations were made as rapidly as possible ; the simplest cases were presented by Tunnels Nos, 1, 4, 5, 6 and 8. The detail sketch of triangulation at Tunnel No. 5, illustrates a frequent method of treatment. In general the data desired were the length of a line, as $B\,E$, Tunnel No. 5, connecting two stations at opposite ends of the tunnel, and the angles made by this line with the tangents into and out of the tunnel.

Let us suppose this information given by triangulation and the line

$$BE = C$$

The angle made by tangent at B with $BE = B$

" " " E " $= E$

" of intersection between the two tangents $= B + E = I$.

The perpendicular let fall from point E on to tangent at B, produced, $= b$

we then have 1st, $b = C \sin. B$

and 2d, $b = R \tan. \frac{1}{2} I \sin. I$

$= R (1 - \cos. I)$

Whence $R = \dfrac{C \sin. B}{1 - \cos. I}$,

in which R is the radius of curve to be used. This expression, representing the relation between the line and angles named, may be taken as an expression for most of the tunnel lines. It was used in this, or in a a modified form, in Tunnels Nos. 1, 2, 3, 5 and 8. Tunnel No. 4 was on a straight line, practically.

The location of Tunnel No. 1 included that of Bridge No. 6, the upper end of which was at the tunnel's mouth. The tunnel began with a curve of 76.3 M. (250 ft.) radius, which extended about half way through it, and ended with a straight line.

It was very important that the tunnel work should be pushed rapidly on account of the difficulty of transportation by mule road through the cañon, and since from the necessities of the case this work would be slower than any other, it would determine the time of the completion of the work on the division. Much attention was paid, therefore, to shortening the tunnels and providing means of entering them between the ends. The adits or galleries in the side of the tunnel took the place of shafts, and were placed, when possible, at points easiest of access, and in such position generally as to divide the work for rapidity of execution.

Each day spent in driving the adit counted twice against the time of completion of the tunnel.

Tunnel No. 3 had been placed on preliminary location at a length of 500 meters (1 640 ft.), its center line would have been about 50 meters (164 ft.) distant from the river wall, as shown on section *E F*, Plate No. 2. Even supposing the use of three adits in the side, these would have averaged 40 meters (= 131 $\frac{2}{10}$ ft.) each in length, and the time of driving the tunnel would have been at least equal to that of driving a tunnel 160 meters long.

A bench, or break in the slope of the river wall, occurred between Tunnels Nos. 3 and 4, with just room enough for the road bed on solid rock in side cut, averaging about 12 meters (39 ft.) deep for 200 meters (656 ft.) in length. Throwing the line on to this bench reduced the length of Tunnel No. 3 to 253 meters (829 $\frac{8}{10}$ ft.), which we were able to divide again by the adit on line *A S* Plate No. 2.

A B was a base line measured on a narrow strip exposed at low water and submerged several feet at high water; *B* to *C* was inaccessible for purposes of measurement; *I* was a point located at the entrance of the adit after the work began, and *P* a point established on line *A S* produced.

The tunnel line was assumed parallel to the base line *A B*, and placed 16 meters (52½ ft.) from it, horizontally, this distance being determined by the position of the point *F*, outside the tunnel.

The cliff through which the tunnel ran was stratified at low inclination, and cleft with distinct and often open joints perpendicular to the plane of stratification. The river for a distance followed one of these joints, the base line was made parallel to them, and it was thought that the straight portion of the tunnel would be more easily driven if made parallel also to the plane of these joints. This plan had its defects in execution, since it favored the opening of a large crack in the roof just above the adit.

The rock wall outside the tunnel was never less than eight meters (26¼ ft.) thick, excepting at the adit, which ran through a soft rock material, filling a large cleft at right angles to the strata and the principal joints.

The strata were bent between Tunnels 1 and 5 into a high arch. Coal seams just under Tunnel No. 1 appeared high over Tunnel No. 3, and ran under Tunnel No. 5 at the river level. The road bed cut the strata

in Tunnel No. 1 at about 45°, and in No. 5 cut them again at about 30° inclination.

At Tunnel No. 6 we were unable to get foot hold on the opposite side of the river without great difficulty. The tunnel line could be produced on top of the tunnel and at *E*, by deflection; the point *F* could be set beyond the tunnel. *A B* was the measured base; *C* and *D* were points carefully selected on the river wall opposite; stations merely, without flagmen. The point *G* was established on the line *G H*, parallel to *F E*, and the location continued from that point.

In getting on to the Pampa Encerrada (pampa is used here in its limited sense) we had been let down by ropes from above, over cliffs 200 feet high.

It was difficult to look into or out from this little space, excepting in a vertical direction; the road to it was improved later, though always bad; several lives were lost during construction, in getting to and from the work. Tunnel No. 7 was, therefore, particularly difficult of access on the western or lower end; from this end all the adits were approached along the river edge to adit *C*, and on staging built out over the river from *C* to *d*.

The base line *A B* was measured on a piece of the gravel flats before referred to; beyond *D* both walls of the river became vertical. The points *a*, *b*, *c* and *d* were reached by long ladders from below, up which men climbed to the level of grade, and set iron plugs in holes drilled to receive them. The adit at *b* occurred in another of the clefts filled with softer rock. Station *E* was 90 meters (295 ft.) vertically above grade of tunnel.

On the plan (Plate XX.) full lines represent visual lines, the heavier ones indicating lines of primary triangulation. *D s*, *F p* and *d V* gave direction of the adits at corresponding points. The adit *b s* was 6 $\frac{37}{100}$ meters (21 ft.) long; the others were shorter, *C* being scarcely more than 3 meters (about 10 ft.). *I* was a point outside of the tunnel at its upper end, and was assumed to be on a tangent from the tunnel. Taking *p* at the intersection of the two lines *F p* and *I K*, simplified the work, since *p* could be set in the tunnel, and the center could be established by tangent deflections until the point of tangency could be set, from which the curve could be run backward. The determination of the point *s* was more difficult; from the intersection angle *k* and assumed radius of curve, 235½ meters (772 $\frac{4}{10}$ feet,), we could locate the point of curvature

q'; the distance $D\,s$ resulted from solution of two triangles $D\,q\,O$ and $D\,s\,O$, where O is the center of the curve $q\,s$.

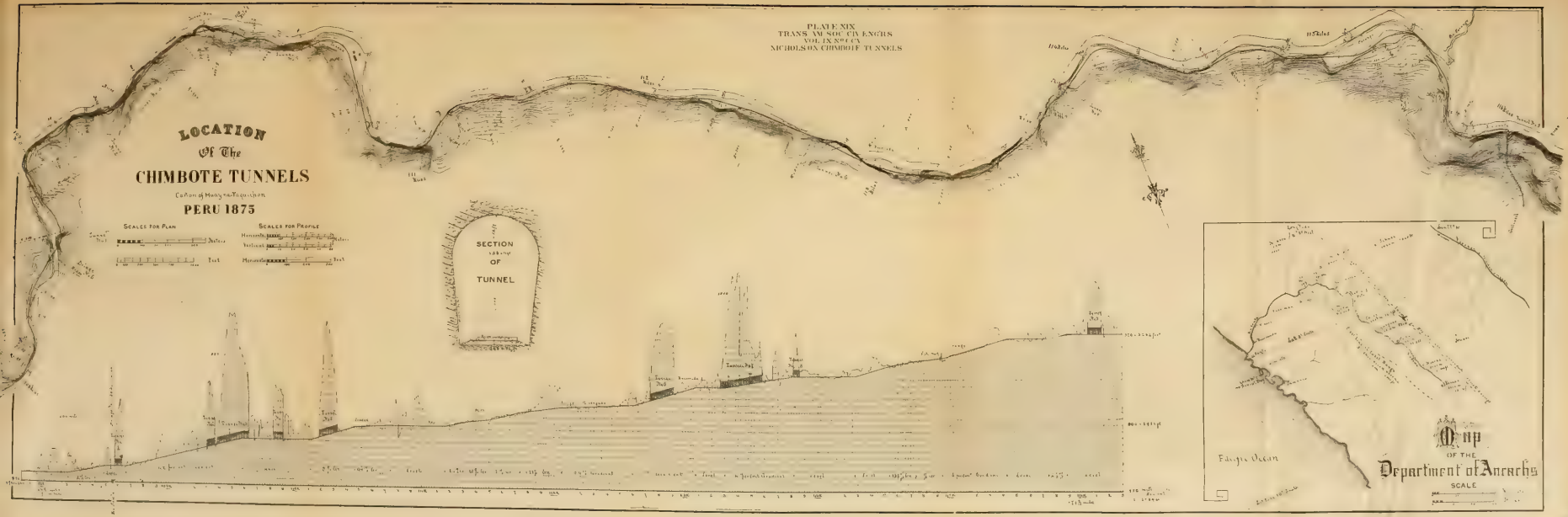
$I\,r$ was taken equal to the difference between the calculated length of $G\,I$ and $G\,r$, $= 17.36$; measured on the ground it was 17.368 meters long; this, though not exactly a proof of the accuracy of the triangulation, served to increase our confidence in the work.

In the location of Tunnel No. 9, which was only regarded as preliminary, the method of Stadia measurement was used for the determination of the chord line referred to in connection with Tunnel No. 5. In definitive location a more extended triangulation would have been made, as in the other instances, preparatory to construction.

In measurement of base lines, Chesterman's steel tapes were used, the measurements being repeated several times in short lengths and between level supports.

The work was done in a climate of almost uniform temperature, and the results obtained justified the means employed. The transit instruments used were generally English, principally of Elliott's make; the vernier read to twenty seconds with good degree of accuracy. All angles were repeated from three to twenty times; where all three angles could be observed, a great number of repetitions was not insisted upon, unless the results were quite unsatisfactory. Seldom, however, were more than five repetitions necessary. A steady breeze blew up the river from ten o'clock in the morning until sunset, and we were often compelled to anticipate its arrival in taking angles from exposed stations.

All observed angles were taken between 30° and 120° where possible. The rule in field work was to establish all stations with greatest security and so that the stake could be seen from the instrument if possible, even at the risk of labor and inconvenience in getting to and from them. At Tunnel No. 3 stakes of 3×4-inch timber were driven into the earth, or $1\frac{1}{2}$-inch plugs were driven into holes drilled in the rock. A hole bored in these received a No. 8 wire about one foot long, carrying a small red flag at its end; when the instrument was at the station the wire was removed and the instrument set over the hole. Much time was saved in sending men from station to station by use of this method. It will be observed that the angles at Tunnel No. 3 were often small; this seemed unavoidable; there was frequently 60 to 80 meters difference in level between the stations.


LOCATION
Of The
CHIMBOTE TUNNELS
Canon of Huaylas to Taquishon
PERU 1875
Scales for Plan
Scales for Profile
SECTION
OF
TUNNEL
Pacific Ocean
Map
OF THE
Department of Ancachs
SCALE

In the summer of 1874 construction began in the cañon; the contract had been sublet to Mr. E. C. DuBois, member of the Society, who, I believe, still holds it; the administration was reorganized, and Mr. Jas. R. Maxwell, member of the Society, was made chief engineer. For more than a year the work was pushed with great energy. The work from kilometer 108 to Tunnel No. 6 was conducted under the immediate charge of Mr. E. T. Scovill, member of the Society, while Mr. D. W. C. Perry had immediate charge from Tunnel No. 6 to the end of the work opened in construction, a point about one-half mile beyond Tunnel No. 9, and including upper heading of Tunnel No. 6. The headings in Tunnels Nos. 1, 2, 3, 4, 5 and 6 had met, and these tunnels were about finished. Tunnel No. 7 was well under way, and with the opening of Tunnel No. 6, more easily approached, when in August, 1875, the work was stopped, as before mentioned.

In Tunnel No. 3, the lines met within two (2) centimeters ($\frac{3}{4}$″) and the results in Tunnels Nos. 1, 2, 4, 5 and 6 were very satisfactory, though not always as accurate as this. The table herewith shows monthly progress at the several headings, as well as best daily progress in all the tunnels. The shorter tunnels were not hurried through, excepting in case of Nos. 1 and 4, where the work had been given to energetic workmen as task work. Tunnel No. 3 was pushed with most energy. This tunnel and No. 2 had been taken together as a sub-contract by one man, a Cornish miner; Tunnels Nos. 6, 7 and 8 constituted another sub-contract under a Frenchman who had had much experience in rock work, particularly in Algiers. Between Tunnels Nos. 2 and 3, a rope ladder led vertically 50 feet from the tunnels to a small spot 100 feet square, and not level by any means, where houses were built, tents put up and a store established, and where the workmen employed in the two tunnels lived; a steep, zig-zag road about 2 feet wide led to the main mule road about 200 feet in elevation above the camp.

The tunnel section as stipulated for in the Government specifications, was 5 meters ($16\frac{4}{10}$ feet) in height above sub-grade, 3 meters ($9\frac{8}{10}\frac{4}{0}$ feet) wide at springing of arch, and about $2\frac{1}{2}$ meters (= $8\frac{1}{4}$ feet) wide at sub-grade. There was nothing in the specifications to prevent use of this section on curves of 61 meters (200 feet) radius. Radii of less than 76.30 meters (250 feet) were never used on the Division, and the width of tunnel section at springing of arch was made 3.36 meters (= 11 feet) in practice, the sides sloping at slope of $\frac{1}{10}$ to 1. The area of tunnel sec-

tion was about 15 square meters, 5 of which at top were taken out in heading, and the remaining 10 meters in bottom were removed in enlargement.

About 600 "Chilenos" and Peruvians were employed in the cañon. The Peruvians were mainly inexperienced in railway or mining work, and were valuable chiefly as laborers until they became accustomed to use of hammer and drill. They received about 80 cents per day. The "Chilenos" were more energetic and hardy, and hence, perhaps, more troublesome. From long experience in the mines of Chili and in the tunnels of the Lima and Oroya line in Peru, they had become valuable tunnel men. They generally received $2 to $2.50 per day for day work, but did much better at task work, and were allowed $50 for labor of driving heading and $40 for labor of enlargement per lineal meter of tunnel. Most of the rock was very hard to drill, frequently using up 12 to 20 good points in a hole 18 inches deep. The limited width of the tunnels prevented use of more than two gangs of drillers in heading, who drilled 6 holes each in day turn and 7 in night turn, each hole being 18 inches deep; the holes were drilled near the outside of the section, the middle portion being broken out by wedges. It is perhaps impossible to make a valuable comparison, but I should think the progress and the cost of work in these narrow tunnels were 25 per cent. less and greater respectively than on the Lima and Oroya line when the tunnels were 50 per cent. wider for a broad gauge road.

The use of pure nitro-glycerine was not permitted by the Government. Dynamite was generally used in the heading holes, as powder seemed almost useless for driving the heading and its use was studiously avoided for this purpose.

The work was so managed as to ensure economical results, very small profits inured to the sub-contractors, while by contract work many of the evils incident to day labor were avoided. Materials of every kind used in camp and on the work had to be brought from the coast. The distance to end of track was about 50 miles; transportation over this distance was effected by mules, and the cost of carrying a single cargo of 250 pounds was about $10.

As has been stated, the cost of labor on heading was about $10 per cubic meter, and on enlargement the cost of labor was about $4 per cubic meter. The cost of explosives, lights, tools, blacksmith's work, and wages to foreman would double these figures.

Monthly Progress of Work on Chimbote Tunnels, Peru, 1874 and 1875.

Name of Tunnel.	Work Begun.	1874. September. Meters.	1874. September. Feet.	1874. October. Meters.	1874. October. Feet.	1874. November. Meters.	1874. November. Feet.	1874. December. Meters.	1874. December. Feet.	1875. January. Meters.	1875. January. Feet.	1875. February. Meters.	1875. February. Feet.	1875. March. Meters.	1875. March. Feet.	1875. April. Meters.	1875. April. Feet.	1875. May. Meters.	1875. May. Feet.	1875. June. Meters.	1875. June. Feet.	1875. July. Meters.	1875. July. Feet.	1875. August. Meters.	1875. August. Feet.	Best Daily Progress. Meters.	Best Daily Progress. Feet.	Work on Heading Completed	Length of Tunnel. Meters.	Length of Tunnel. Feet.	Remarks
No. 1, upper end	Nov. 1874	....	....	....	....	11	36.1	10	32.8	16	52.5	5	16.4	8	26.2	....	....	....	....	....	....	....	....	....	....	0.97	3.2	April 20, 1875.	50	164.0	22 hours work daily. Hard and compact material, solid but not hard to drill.
" 2, " heading	" "	....	....	....	....	14	45.9	5	16.4	9	29.5	4	13.1	12	39.4	5	16.4	6	19.7	8	26.2	....	....	....	....	0.73	2.4	June 24th.	63	206.6	22 hours daily.
" 3, " "	Oct. "	....	....	10	32.8	14	45.9	11	36.1	12	39.4	10	32.8	10	32.8	6	19.7	5	16.4	5	16.4	....	....	....	....	....	....	" 12th.			22 hours work daily.
" 3, adit upper heading	" "	....	....	5	16.4	8	26.2	10	32.8	10	32.8	10	32.8	7	23.0	5	16.4	5	16.4	4	13.1	....	....	....	....	0.89	2.6				Hard and compact at ends.
" " lower "	" "	....	....	3	9.8	7	22.9	13	42.6	14	45.9	5	16.4	....	....	....	....	....	....	....	....	....	....	....	....	0.89	2.6	Feb. 20th.	253	829.9	Hard to drill and broken, with seams in middle.
" 3, lower "	" "	....	....	13	42.6	16	52.5	14	45.9	13	42.6	8	26.2	....	....	....	....	....	....	....	....	....	....	....	....	....	....				
" 4, upper "	Sept. "	4	13.1	12	39.4	17	55.8	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0.71	2.3	Dec. 1st.	70	229.6	22 hours work daily. Hard to drill but loose in places.
" 4, lower "	" "	7	22.9	14	45.9	16	52.5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....				
" 5, upper "	" "	10	32.8	16	52.5	17	55.8	18	59.0	18	59.0	12	39.4	....	....	....	....	....	....	....	....	....	....	....	....	0.83	2.7	Feb. 19th	140	459.2	Hard and solid lower end, loose in upper end. 22 hours work daily.
" 5, lower "	Nov. "	....	....	4	13.1	6	19.7	13	42.6	14	45.9	12	39.4	....	....	....	....	....	....	....	....	....	....	....	....	....	....				
" 6, upper "	Oct. "	....	....	8	26.2	12	39.4	9	29.5	7	23.0	2	6.6	7	23.0	8	26.2	8	26.2	5	16.4	15	49.2	12	39.4	0.72	2.4	Aug. 19th.	180	590.4	Hard and compact at ends; loose in centre. 22 hours work daily.
" 6, lower "	Nov. "	....	....	....	....	8	26.2	11	36.1	7	23.0	2	6.6	9	29.5	5	16.4	9	29.5	9	29.5	15	49.2	12	39.4	....	....				
" 7, " "	Mch. 31st, 1875.	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	13.1	8	26.2	6	19.7	8	26.2	3	9.8	0.28	0.9				Work stopped August 25th.
" 7, adit b, lower heading	April, "	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	6.6	5	16.4	5	16.4	4	13.1	8	26.2	....	....				No. 7 Tunnel worked only 10 hours per day
" 7, " upper "	" "	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	6.6	3	9.8	9	29.5	5	16.4	5	16.4	....	....				
" 7, " c, lower "	" "	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2	6.6	2	6.6	3	9.8	5	16.4	4	13.1	....	....		319	1046.3	Very hard and compact material, and difficult of access.
" 7, " upper "	" "	....	....	....	....	....	....	....	....	....	....	....	....	....	....	7	22.9	8	26.2	6	19.7	7	23.0	6	19.7	....	....				
" 7, " d, lower "	May, "	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	13.1	7	23.0	6	19.7	4	13.1	....	....				
" 7, " upper "	" "	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	13.1	7	23.0	8	26.2	3	9.8	....	....				
" 7, upper heading	April, "	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	9.8	5	16.4	7	23.0	8	26.2	5	16.4	....	....				
" 8, lower "	" "	....	....	....	....	....	....	....	....	....	....	....	....	....	....	4	13.1	4	13.1	6	19.7	10	32.8	....	....	0.34	1.1	July 31st.	50	164.0	Very hard and compact.
" 8, upper "	Mch. 31st, "	....	....	....	....	....	....	....	....	....	....	....	....	....	....	6	19.7	6	19.7	6	19.7	8	26.2	....	....	....	....				Rock. Worked 10 hours per day.
Total		21	68.8	85	278.7	146	478.9	114	373.8	120	393.6	70	229.7	53	173.9	79	193.5	82	268.8	93	305.1	99	324.6	62	203.3				1 125	3690.0	

The cost of Tunnels Nos. 2 and 3 was about $12 per cubic meter = $10 per cubic yard.

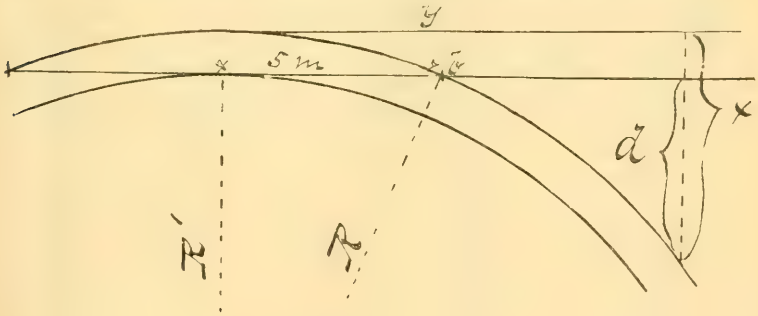
The cost of Tunnels Nos. 6 and 7 was about $14 per meter = $11.70 per cubic yard.

I believe as high as $105 per linear meter was paid on Tunnels 6 and 7 for labor in excavation.

When the rock was loose the roof would be quite unreliable, and provisions had been made for some lining at ends of Tunnels 3 and 4, and may prove necessary at other points.

Line was generally given in tunnels at every few meters of progress. The method of fixing plugs in the roof was not used excepting for important points requiring to be set before bottom was taken out. Since the enlargement followed the heading within about ten to twenty meters it was always possible to keep plugs in the tunnel bottom over which instruments could be easily set. When plugs could be conveniently set in the roof at ten meters apart a table of deflections was sometimes given to direct the workmen until instruments could again be brought into the tunnel.

Two examples are given below of these tables for curves of 120.8 meters, and 301.6 meters radius. The deflections are given for each meter of the chord produced, and were obtained by deducting difference of radii of circumscribed and inscribed circles from the values of ordinates to the circle corresponding in position to the desired deflections.

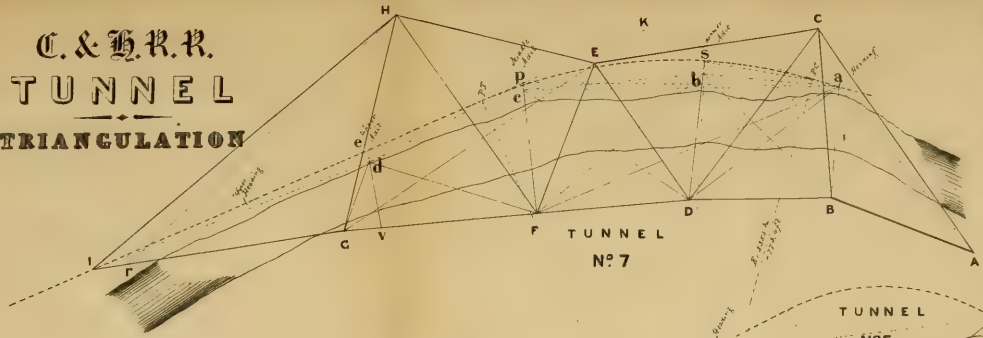


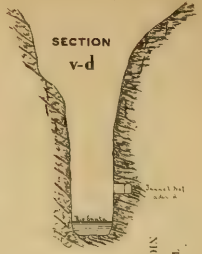
$R = 120.8$ Meters. $R' = 120.696$ Meters.				$R = 301.574$ Meters. $R' = 301.429$ Meters.			
Distance on chord produced from b.		Values of deflection or offset $= d$.		Distance on chord produced from b.		Deflection or offset $= d$.	
0	meters.	0.0	meters.	0	meters.	0.0	meters.
1	"	0.041	"	1	"	0.013	"
2	"	0.099	"	2	"	0.039	"
3	"	0.162	"	3	"	0.065	"
4	"	0.231	"	4	"	0.093	"
5	"	0.312	"	5	"	0.124	"
6	"	0.402	"	6	"	0.159	"
7	"	0.498	"	7	"	0.194	"
8	"	0.602	"	8	"	0.240	"
9	"	0.714	"	9	"	0.284	"
10	"	0.835	"	10	"	0.333	"

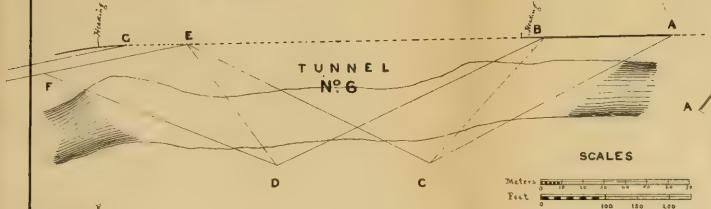
The comparative ease with which the work in the long tunnel represented on the preliminary study at 2 100 meters had been reduced in the five small tunnels by use of sharp curves, narrow road-bed, and close examination of the cañon, leads me to believe that the cañon of Pato, often referred to as *the* cañon of the Santa, would lose many of its terrors on closer examination. A glimpse once obtained into the lower end of this cañon, with some knowledge of the district surrounding it, convinces me that the difficulties would not be greater per mile than those of the lower cañon already passed.

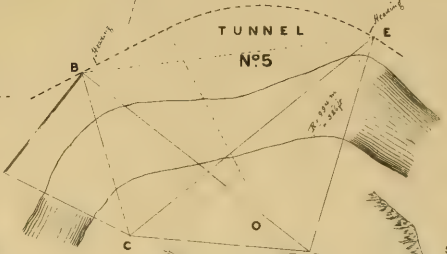
Peru has fallen upon unfortunate experience of late. Whether the Chimbote and Huaraz Railway will ever be completed is, indeed, a question of the future, but it is certain that none of all her projected railways deserves more careful attention, or possesses greater interest.

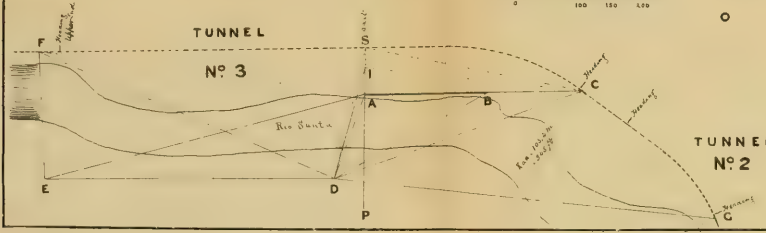
C. & H. R. R.
TUNNEL
TRIANGULATION

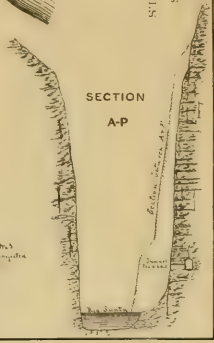












TUNNEL
Nº 2

PLAN AND SECTIONS OF TUNNELS
TRANSMITTED BY MR. THOMAS SARGENT
MICHOACAN

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCVI.

(Vol. IX.—October, 1880.)

PRACTICAL CONSEQUENCES OF VARIATION OF THE WET SECTION OF RIVERS UNDER GENERAL AND SPECIAL CONDITIONS.

By ROBERT E. MCMATH, Member of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, MAY 25TH, 1880.

The particular theme in view requires the consideration of effective cross-section, and the influence which change of the several elements that enter into it has upon the flow of water, the maintenance of channels, and the many practical issues which depend upon them.

The idea of effective cross-section is an abstraction or a generalization which gathers into one expression all the facts and influences affecting the discharge at a given point. For a given stream at a given time the product of area and velocity is a constant; therefore their variations must be simultaneous, opposite in sign, and in equal ratio. But it is soon discovered that equal areas are not equivalent, therefore actual areas do not meet the necessities of logic, and resort is made to the ideal section of equated value, which is called the effective cross-section.

The elements of actual area are few and simple, depth and width The elements of effective section are many and complicated, embracing in addition to depth and width, trace or outline of banks, form of section, contour of bed above and below, character of the bed and banks in respect to roughness and regularity ; also the tenacity or mobility of the material composing the bed and banks. These are permanent elements at a given locality, and there are also temporary elements, such as air currents over the surface, and the presence of accidental obstructions dividing the flowing waters into separate streams, which, while divided, are retarded by frictions, and when reunited, produce eddies and cross-currents.

The naming of these elements (the list is not exhaustive) is sufficient to show that the subject does not lie within the range of precise or mathematical investigation. The only possible mode of general treatment is to assume the simple conditions, examine their effect singly, and then in combinations approaching actual cases.

First assume a stream with straight and parallel banks, a rectangular or other symmetrical cross-section, and a smooth unyielding bed of homogeneous material. Obviously these are the conditions suited to an uniform effective section, and equal areas of similar figure taken at different parts of the section will have equivalent value, except as affected by variation of velocity in the horizontal and vertical directions. In this case these curves may be considered regular, the former symmetric about the axis of the section. Increase or decrease of volume will produce no radical change in any of the conditions.

Next, suppose the trace a well defined curve, other conditions as before. The equivalence of equal and similar areas, symmetrically situated with reference to an axial line, disappears as a result of the tangential force, and the horizontal curve of velocity is no longer symmetrical. If the cross-section be released from the arbitrary condition of symmetry, the natural arrangement will be a shelving shore on the convex side, and an abrupt bank on the concave, whence a greater disturbance of the equivalence of areas will follow, and additional distortion to the curve of velocities. Variation of volume will now overthrow the condition of parallelism, for the change in the form of cross-section just allowed will be gradual from the straight trace and symmetrical section, to the point of greatest curvature and concentration of current. Therefore, the outline on the convex side at a low stage cannot be parallel to that at a

higher, and if the condition of parallelism of the two banks, or uniform width, was imposed at a high stage, it will be broken at a low, and *vice versa*.

Under the conditions now supposed, another phenomenon will manifest itself with change of volume, which may be defined as vagation of the axis of greatest velocity. The gentle slope of the convex shore occasions considerable change of width as the waters rise and fall, hence the centre of figure will travel toward the concave bank during decline, and toward the convex side during the rise. If the hydraulic axis of the stream be taken at several stages, by multiplying each element of cross-section by the velocity of flow at its position, and equating the products about a line, which is equivalent in determining the axis of the discharge, the gyration of the hydraulic axis with change of stage becomes evident, also that the range of its movement is greater or less than that of centre of figure, as the axis of greatest velocity falls on one side or the other of that centre. This in part follows from the augmented effectiveness of the areas as the depth of flow is increased.

Effectiveness, other conditions being the same, varies as the square roots of the depths ; therefore the rate of variation in effectiveness is more rapid in the shoal than in the deep parts of the section. When the waters rise, the velocities in different parts of the section approach uniformity, but so long as the view is restricted to the single idea of form of section, it does not appear that they can reach, much less pass, that limit into the condition of greatest velocity not coinciding with greatest depth, which it is well known often occurs.

Considering that the hydraulic axis represents the actual stream, it will appear that any change in its position is virtually a change in the trace of the whole stream, which will indirectly lead to modified form of section, and directly cause increase or decrease of velocity, by the variation in length of trace which is inseparably connected with change of position. The relative velocities in the several parts of the section will also be affected by the change of curvature or trace. In Fig. 1, Plate XXI., the broken line represents the trace of the hydraulic axis at a low stage, the dotted line the more direct trace at high water.

The variations of the hydraulic axis during a rise are almost invariably in the sense of straightening, whence the course of the current is shorter and the slope greater at high stage than at low. The actual velocity along the concave bank may not be diminished, but the increase on the

opposite is often great enough to render it relatively less, whereas it was the greater.

It is, perhaps, necessary to say that this reasoning does not apply with equal force to every curve, or to all parts of the same curve, at a given time, but to each in its own time and order. The law by which currents incline toward concave banks always holds good. But the action of this and other laws varies in position, as the volume is increased or diminished, by a law also absolute.

If in pursuing the study, the remaining condition of unyielding bed and banks be released, the stream assumes the natural type of a river traversing an alluvial region. The variations of the flow will exert an influence upon the bed and banks hostile to their stability. But if the stream be a silt bearer and the bed extremely unstable, the cross-section will strive to adapt itself to the changing conditions of flow, with a readiness of adjustment which tempts the observer to forget that the power of adaptation is subject to limits of extent and time. Without such limits the condition of uniform motion would be attained.

By this partial adjustment a fill will occur on the convex and scour along the concave side during the declining and low stages, and the straightened, shortened trace, during the rising and flood stage will, to a limited extent, develop a tendency to scour the convex, and in some cases to fill the concave side. The first of these statements will probably not be questioned. Owing to the progressive erosion of bends, and the permanent extension of points, the scour of the convex side in time of flood is concealed, except as obscurely indicated by the flattened profile of shore bars and their frequent separation from the point by high water chutes, because the eroded material is replaced during the decline. The limited filling on the concave side quite often remains in fragmentary patches of mud, visible when the water falls. Citation of particular facts, or the testimony of individual observers, is not consistent with the purpose of this paper.

The fact that the extremes of volume have a contrary influence upon the cross-section involves necessarily a transition period of no action, and consideration of the changed trace of the hydraulic axis determines that the point of action, be it scour or fill, will vary with every change of stage. Therefore all parts of an extended bend will never be affected in the same sense at the same time ; but in a stream having well defined succession of high and low stage all parts will in turn be subject to action

in proportion to the duration of particular stages. If the changes of stage are always progressive from one extreme to the other, the curves will be regular. Interruption of a progressive change, or irregularity of period, occasions confusion of curvature, whence the outline of a bend usually presents a succession of intersecting curves. In general terms, the condition of scour will prevail where the hydraulic axis is convergent to the bank, fill where the axis diverges from the bank, and no action where axis and bank are parallel. It is therefore impossible to trace in detail the action of the general law that change of form, position, and effectiveness of section attends variation of volume in streams which form their own beds. But it is possible to draw the following conclusions, having their application to the curved parts of silt-bearing streams :

1st. High water changes within the bed proper are not, as a rule, lasting, being commonly more than compensated by the opposite low or falling stage changes. They are not, therefore, hostile to the permanent retention of the stream within fixed limits.

2d. Low stage changes can only be controlled by preventing erosion of the concave bank.

3d. If erosion of the concave bank is checked the force of the stream will be expended in widening and deepening the low-water section, chiefly the latter. No protection of banks can therefore be permanent unless the foundations extend to the depth of this probable scour, or protection be given to the bottom. The necessity for deep foundations will generally be limited to the upstream part of the bends where the low-water action is most intense.

4th. The slackening of the currents at high water along the upstream part of the bends renders the artificial protection of the banks above the mid-stage level a matter of secondary importance. The acceleration of the same currents near the lower limits of the bend calls for the effectual protection of the higher parts of the bank, but the foundations will be comparatively secure.

5th. No works designed with reference to the conditions existing at one extreme stage can be operative at the opposite extreme.

6th. The greater the range of volume between the flood and low stages the greater will the extent of change in the cross-section be, and the more serious the attack upon the stability of works erected to establish a given condition.

7th. The opposite effect upon the cross-section, due to extremes of

stage, is one of the conservative compensating principles by which the essential stability of natural arrangements is made possible in the midst of constant change.

In theory, regulation of width seems to promise an equalization of depths and velocities, whence it may be argued that the silt transporting power would be constant, and erosion and deposit must cease. This overlooks the influence of trace and its variations upon the direction and distribution of currents, and so applies generally principles which are good only when limited to straight channels. The equalizations of theory extend only to mean depths and velocities, leaving the variations within the cross-section out of view. Clearly the water which flows along the concave bank in the bend, will pass along the shoal margin of the point below with very different velocity and transporting power, whence it must be that the individual parts of the silt burden undergo continual exchange, even if the total quantity remain constant, therefore fills and erosions are necessary.

Hitherto the changes affecting different parts of the same cross-section have been considered. The next study will be the more general changes which cause difference in effectiveness of sections more or less closely related to each other by position. The imposition of arbitrary conditions is no longer necessary, and the study will be of things as they are, referring to experience and observation for verification of statements necessary to the argument.

In a series of cross-sections extending to the mean level of the principal banks, if the variation of width is gradual but considerable, the location of the section of greatest efficiency will be variable with the volume, and the locations of related sections of greatest and least efficiency will interchange as the stream rises above or falls below a particular stage. The velocity at the narrowest section will be a maximum when the flood is at the highest, and a minimum when the volume is least. At the widest section the converse is true in a limited sense.

Let Fig. 2 (Plate XXI.), represent the section of least width in the series, whether located in a bend or not is immaterial, except that in a bend the form of section is definite and like the figure.

Fig. 3 represents the section of greatest width in the series. The shaded lines represent the bottom of the sections at a particular stage when the areas of the two sections are equal. The upper and lower

horizontal lines are the water surface at the extreme stages, and the intermediate line is the stage corresponding to equal areas.

It will be necessary to remember, since by the general formula $V = C\sqrt{r\,s}$, that in similar channels, other conditions being equal, the velocities are as the square roots of the hydraulic mean depths; therefore the velocity at any particular point in a cross-section will vary nearly as the square root of the depth at that point, when the river rises or falls, and the mean velocities of the sections as a whole will vary nearly as the square roots of the mean depths; for in large rivers the difference between mean and hydraulic mean depth is inconsiderable. A quantity, which varies as the square roots of an arithmetical series, will have a rate of variation rapid at the beginning of the series but becoming smaller as the terms of the series increase, like the ordinates of the curve whose equation is $y^2 = x$.

Since the mean depths at the stage of equal areas are unequal, being in the case inversely as the widths, the equal areas of the two sections will not with a given slope pass an equal volume. In order that the volume, which must be the same at the two sections, may be discharged, the mean velocity at the shoal section must be made equal to that of the deeper one by a steeper local slope. If the river falls, the areas will diminish unequally, the wide section losing the most. The diminution of depth will also affect the hydraulic capacity of the shoal section much more than the deeper. The now unequal areas have a still greater difference of effectiveness than before, consequently the velocity and slope at the shoal section must each undergo a very considerable increase, and at the deep section a slight decrease. Carried further, the shoal becomes the location of riffles or even rapids, and the deep places pools without apparent motion at low water.

Returning to the stage of equal area, and supposing the river to rise, the increase of area and effectiveness will be more rapid at the wider section, wherefore the capacity for discharge will speedily overtake that of the narrower, and the mean velocities will be equal with equal slope. If the rise continues, the wide section becomes the more effective, and the greater velocity and local slope pass to the narrow section. The difference of velocity at the sections will increase as the height of the flood increases, the current in the narrow parts of the river becoming stronger, and in the wider parts comparatively slack. But the range of slope and

velocity between extremes will be much greater at the wide section than at the narrow.

These changes with the stage are familiar facts to every one acquainted with streams of stable beds. In a silt-bearing stream, traversing a bed whose material is readily moved by currents, the influence of the varying effectiveness is divided between changes at the bottom and the exchanges of velocity described above. The effort being to equalize the effectiveness of cross-sections, and so maintain uniform motion, quickening of velocity is in such streams checked by enlargement of area through erosion, and slackening by diminished area through deposit. The adjustment, in the interest of equalized section and uniform velocity, will be the closer as the mobility of the material composing the bed increases.

It is, therefore, demonstrated that in silt-bearing streams, traversing beds composed of their own deposits, a building up of bars and shoals in the wide places, and a scour in the narrower, must occur in time of flood, and a waste or scour of the shoals, with fill in some part of the pool below, must occur as the river falls to a low stage.

Reproducing the sections as Figs. 4 and 5, the dotted lines are added to represent the probable sections at the extreme low stage, and the broken lines the same at the culmination of the flood. The contrary effect at the extremes involves a transition period of no action upon the bed. This period plainly must coincide with the nearly equal velocity which accompanies equal efficiency of sections. This equality occurs at a particular stage as the river rises, and again as it falls. Is this particular stage the same in each case, and at all rises and falls, or is it variable ?

Equivalence of areas is the test, and exists when the area at the wide section is somewhat greater than at the narrow, the occurrence of these conditions can be determined approximately, and the question answered. If the river be supposed to have fallen from the intermediate stage of equal area to low water, and the sections to be changed from the shaded to the dotted outline, a line to cut off equal areas of the new sections must be drawn considerably below the intermediate line of former equal areas. As the increase of velocity at the shoal section in the case of unchanging bed was much greater than the decrease at the deep one, in the present case section changes replace velocity change in part, and must measurably be in the same proportion ; therefore, the scour at the

wide section must be greater than the fill at the narrow, and the line cutting off equal areas will be lowered. The lines cutting off equivalent areas will lie slightly higher on the wide, and lower on the narrow section, than the line of equal areas. Therefore, the closer the adjustment to equal effectiveness at the low stage, the less the rise required to bring the conditions into the opposite relation, and make fill take the place of scour.

This is verified at the wide shoal sections, by the well known fact that a minor rise coming after the channel has commenced to "cut out" will work positive disadvantage to the channel depth by causing "flattening."

On the other hand, supposing the river to have risen from the intermediate stage of equal area to bank full, and the section to have changed from the shaded to the broken outline, it will readily appear that the fill at the wide section will greatly exceed the scour at the narrow, and that the condition of equal area will be reached on the decline long before the stage falls to the level of the intermediate line.

Putting the results at the extremes together, it is proven that the vertical range of the crest of the shoal may be a very considerable fraction of the rise and fall of water surface. Also it is certain that the transition stage is variable, occurring earlier, both in rise and fall, as the preceding low or high stage has by joint influence of volume and duration adjusted the bed to the discharge of such volume with uniform velocity.

It has now been proven that

1st. There is a tendency to adjustment of the conditions of flow in the interest of uniform motion under which the stream continually reforms and rearranges its bed as the volume varies. If the volume remain constant for a sensible period, the adjustment to the conditions will be perfected and remain stable. But if the variations of volume be rapid, extreme, or irregularly alternating, the results are imperfect. Volume is the agent, but requires time to operate. Duration, therefore, measures the effect as much if not more potently than the actual range of volume.

2d. There must be a movement of material off from the shoals into the pools, and out of the pools upon the shoals as the stream rises and falls.

3d. This alternating movement between pool and shoal is the general

law governing the movements of silt along the bottom of rivers, irrespective in this connection of the mode in which the material is transported, whether it be by intermittent suspension, or by being swept along the bottom.

4th. Since this alternating movement follows the variation of stage, the higher the flood and the longer it continues, the more considerable the mass and the greater the height of deposit on the shoals, and the longer the low stage continues, the deeper and better the channels which will be cut through the shoals by a given volume.

The practical consequences of the movement, therefore, extend in two directions, which may or may not be harmonized. The one affecting the flow of the waters, or the discharge of floods, the other the navigability of the channels.

If the first of these be examined, the fact under discussion will be recognized as an efficient equalizer of velocity, adapted to the natural condition of great variation of volume in an unstable bed, by which the evil consequences of extremes are neutralized by their succeeding each other in a more or less perfect alternation, and the river guarded against extended radical changes by the forces being compelled to exhaust themselves upon local action. But, since the action at extremes of stage produces contrary results at the places where amelioration of conditions in the interest of navigability is most necessary, that is, the wide reaches, the increase of flood volume by concentration is opposed to the permanence of low-water channels.

Therefore the changes of wet section due to the variation of width harmonize with similar changes due to outline in demanding recognition of the principle, that variations of volume are to be lessened, if practicable, never designedly increased, by engineering works.

The alternating silt movement is the apparent cause of obstructed navigation in rivers whose beds are unstable; for, if the crests of the shoals continued throughout the year at their low stage elevation, the depth would, except for very short periods, be ample for all the requirements of commerce.

Considered in this limited view, the movement appears to be an evil, and the naturally suggested remedy is to obliterate the shoals by reducing the stream to an approximate uniformity of width. Assuming the practicability of doing this to any degree thought advisable, inquiry is pertinent concerning the physical consequences to the stream itself

when the proposed regulation is completed throughout the extent of a great river.

Attention has often been given to the modifying effect upon floods due to the vast volumes of water absorbed in channel filling. To reduce high-water widths to uniformity must materially lessen the reservoir capacity of the river-bed. To shut off lagoons and lateral swamps from the floods by embankment, must also intensify flood effects upon the lower parts of the river so narrowed and embanked. But this is not the point of the present inquiry, which turns rather upon the fact that the waters absorbed by channel and swamp filling during the rise, are given back, little by little, during decline, and so sustain and equalize the discharge. Impairment of the reservoir capacity of a river bed must therefore hasten and prolong the period of low water, and reduce the discharge below the natural limit, and so much the more as the application of such a system of improvement is extended. This suggests that while suppression of the alternating movement, through regulation of width at high stages, promises to remove the apparent cause of obstructed navigation, a worse evil may immediately appear as a direct consequence of such suppression, or rather of a suppression accomplished in this way. To avoid these undesirable secondary consequences of width regulation is an important practical problem, whose theoretical solution is readily found in equalization of volume as an attendant, logically, an antecedent step to regulation. This may not always be practicable ; but no engineer can question that the true principle of conserving and concentrating the natural forces of a river, in the interest of permanence, lies in the direction of equalization of volume.

The practicability of equalizing volume by retaining a portion of the flood waters in artificial reservoirs, to be drawn upon when the natural flow is insufficient for the needs of navigation or irrigation, has often been discussed, and in many cases set aside as unpromising. But if such a system was already constructed and in successful practical operation, without cost to any, a proposition to destroy or impair it should be received and entertained with great caution.

A reservoir system is naturally in operation upon all streams. To measure its importance requires the summation of the area of water surface presented by a great river and its permanent affluents, and an estimate of the volume required to fill the area to a depth equal to the

mean range between high and low water. This natural reservoir, if the bed is not subject to alternate changes, will be speedily drawn off and serve only to mitigate the floods and prolong the high stage. But if the bed is subject to alternation every shoal constitutes a dam, built up in time of flood, which slowly wasted during the decline renders each pool and bend a reservoir to sustain the low water volume, whose area is that of the water surface, and whose depth is the vertical range of the shoal or crest of bar, already shown to be, in rivers of unstable beds, a considerable fraction of the range of water surface.

This specially valuable reservoir action is the direct consequence of the variation of wet section under the special condition of width variable at high water.

Variation of the wet section has now been considered under two forms, one being the consequence of change of trace accompanying variation of volume, manifests itself in the transverse profile and affects stability of banks; the other being the joint result of variations of width and volume, manifests itself in the longitudinal profile and affects the navigable channel. The extent of both forms depends upon the mobility of the material composing the bed, and the duration of particular stages, up to the limit of complete adjustment or uniform motion. Alternation of scour and fill, lateral or longitudinal, is determined by variation of volume, and would be suppressed by equalization.

It has been shown that artificial uniformity of width tends to increase the variation of volume (strictly, it only brings the discharge into closer conformity to the varying supply). From the general argument it follows that stability of the condition of uniformity is endangered by such increased variation. Equalization of volume will bring about stable conditions of bed and banks, and, paradoxical as it may seem, approximate uniformity of width is among the stable conditions so brought into existence.

The general proposition that stable conditions of cross-section attend equalized volume is evidenced by the beds of lake-fed streams and artificial channels of regulated discharge. The fact of uniform width being among the stable conditions is evidenced only by the lower parts of the few silt-bearing rivers traversing an alluvial formation of homogeneous soil extending to depths practically unlimited, whose areas of drainage include such variety of climate as to afford an approximately equalized volume.

Seeking a theory of channel formation in accordance with the facts, it is submitted, that a stream freely forming its own channel in an alluvial plain will be governed by the following principles:

1st A plastic mass moving in a resisting medium will assume the form in which it encounters least resistance.

2d. The transverse section of a body adjusted to the form of least resistance will have the ratio of $\frac{\text{area}}{\text{perimeter}}$ a maximum.

3d. The form of a fluid mass will vary, whenever the direction of movement is changed, by virtue of the unequal moments of inertia in different parts of the mass.

4th. The form being unsymmetrical, and the direction of movement not a straight line, if the mass be variable, the path described by the center of volume or hydraulic axis will be variable also in position and length.

5th. With given limits of mass variation, the vagation of the paths will lie within a zone of certain width.

With these principles in mind, it is readily seen that a river traversing a homogeneous soil will form a bed whose width and depth will be largely determined by the variations of volume, being wider and shoaler as the vagation of hydraulic axis is greater; narrower and deeper, as the volume becomes constant and the vagation of hydraulic axis less. There is nothing in this conclusion which limits it to the lower parts of rivers. That constancy of volume is essential to stability of condition, may, therefore, be put among the principles of general application. This may not be practically realized, but is a valuable index of the direction engineering plans should take; for the converse is equally true. Changeable cross-section and excessive width are in nature inseparable from extreme and irregular variations of volume.

From the preceding partial study of the consequences of variation of wet section, a general conclusion is suggested which involves a more radical distinction than has heretofore been recognized between hydraulics as applied to large streams, and to pipes or other rigid channels.

Hydraulics, as generally understood, is founded upon experiments, and deductions therefrom, made upon channels with boundaries really unyielding, or supposed to be so, and treats velocity as a flexible quantity adapting itself to rigid conditions of area and volume. To some

extent in all rivers, but particularly in silt-bearers with unstable beds, uniform velocity is approximated, and areas become the flexible quantity, or, in a certain sense, the dependant variable. With this important complication of the elements in view, the impossibility of applying the same formulas to the two classes of channels is obvious.

Moreover, since all the elements of area are independent variables, the impossibility of obtaining formulæ of practical value in terms of velocity, slope and hydraulic mean depths is suggested.

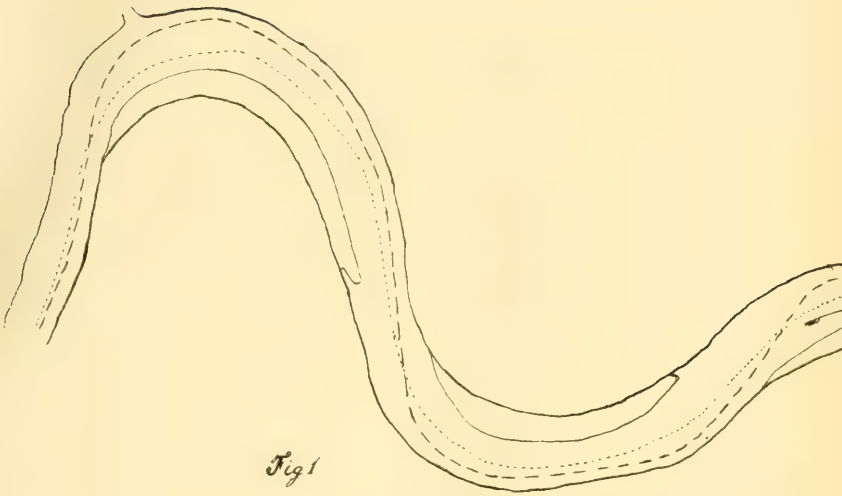


Fig 1

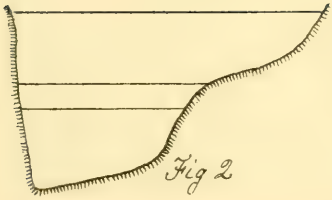


Fig 2

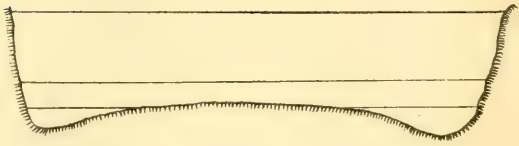


Fig 3.

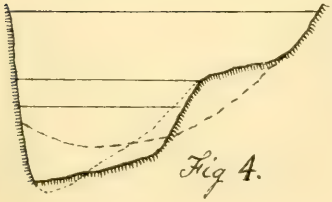


Fig 4.

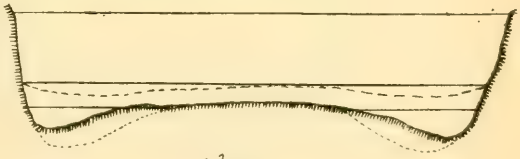


Fig 5.

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CCVII.

(Vol. IX.—October, 1880.)

WIND PRESSURE AGAINST BRIDGES.

By ASHBEL WELCH, Member of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, MAY 25TH, 1880.

With Discussion by C. SHALER SMITH, THEODORE COOPER, JAMES B. EADS and ROBERT BRIGGS.

The disaster to the Tay Bridge caused by the force of the wind, suggests a reconsideration of the rule by which that force on such structures is usually calculated.

In all the calculations I have been able to find, it is assumed that the pressure on a flat surface, at right angles to the wind, is equal to a column of air of the same base as that surface, and of the height that would give a falling body the actual velocity of the wind.

If the particles of air were annihilated instantly after impact, or if they were solids, and instantly dropped or rebounded out of the way, this rule would require but little qualification.

But the real conditions are entirely different from those just supposed. After impact, an additional amount of force pressing against the obstruction must be expended to move the intercepted air sideways out of the way. The air rebounds in divergent lines, and thus a base is pressed upon, broader than the surface of the solid, and yet supported by it. The solid surface may be conceived as a fulcrum supporting a leverage extending each way beyond itself. The pressure must be sufficient not only to stop the original motions of the air, but to generate the new motions that disturb the surrounding atmosphere.

Hence the pressure against the solid flat surface, especially if a narrow one, is always greater than that deduced from the rule in question.

A moving fluid presses upon a fixed obstruction, wide or narrow, continuous or interrupted, with just the amount of force which the obstruction stops. When it diverts any part of the fluid from its original course, I suppose the amount of force stopped is as the sine of the angle of divergence.

A stake set up in the sweep of driving sand, or snow, not only piles it up in front, but for a considerable distance on each side, showing that the stake stops or checks a column of air much wider than itself, and so stops the force and sustains the pressure of a column wider than itself.

It is the same in water. From Beaufoy's careful experiments it appears, that to move a short plank of 3 inches by 20 inches section, endways through the water with a velocity of 8 feet per second, required, besides the force necessary to overcome the friction, a force of 60.69 pounds. By the rule in question it should have required only 26.04 pounds. The actual resistance was two and a third times that which the rule gives. As air is elastic, we should expect that its impact would create greater disturbance around the obstruction than water, and so create a greater pressure in proportion to its velocity and weight.

An orifice through a thin side of a vessel filled with water, relieves that side of only about five-eighths of the pressure which would be upon the area of the orifice if closed up. So the difference between the pressure of the wind against a continuous plate, and against the bars of an iron bridge superstructure of the same height and length as the plate, is not measured by the extent of open space between those bars, but by the *vena contracta*, probably smaller in air than in water.

The area of surface of booms and bars of the superstructure of one

of the longest spans of the Tay Bridge is said to have been 800 square feet. All of the calculations of pressure I have seen are founded on the assumption I have mentioned, and so far as I have seen, that assumption has not been questioned. If the velocity of the wind was 150 feet per second (about 102 miles per hour) the pressure, on that assumption, was 28 pounds per square foot, which on 800 square feet makes 22 400 pounds. I believe with that velocity it was nearer 50 000 pounds.

This subject opens a fine field for investigation by some young scientific bridge building engineer. A very simple and easy experiment is to suspend a system of flat bars of iron or wood, so as accurately to face the wind, and by comparing the extent of its exposed surface, its weight, and deflection from the vertical, to deduce the force against it. Some thing of this kind must often have been done, but I do not think the results, whatever they may be, are generally known.

Discussion of the above Paper.

C. Shaler Smith.—I have taken pains to examine the plans of the Tay Bridge, and accurately calculate the wind surface exposed, by our American rules. Instead of 800 given by the English method, I find it to be 2 576 square feet. That is very easily tested by examination of the plans.

Theodore Cooper.—It is surprising, when we examine our knowledge of the pressure of the wind, to find how little we know, and how unreliable is that little. Engineers have almost universally relied upon the table of wind pressures and velocities first published by Smeaton, without stopping to examine into its reliability or how it was obtained.

On examining into past experiments upon the relation existing between the velocity of the wind and the pressure due to such velocity, we find they were nearly all made by means of rotating arms, with the resisting surfaces fastened at their extremities, the velocities being determined by the revolutions of the arms, and the resistances indirectly by determining the power exerted upon the mechanism. For the purpose of getting a better knowledge of the power of wind-mills, the more immediate purpose of many of these experiments, these experiments may have been well enough; but to rely upon them for the facts upon which to base the designing of our modern structures to resist the wind, seems very unscientific. For moderate velocities the results may have been approximately correct; but for the higher velocities, which are the

important ones for our present purposes, they would be very untrustworthy. The pressure exerted by the fans against air already more or less in motion by the rotation of the fans, would be very different from the pressure of a mass of air moving at the same high velocity striking against a stationary surface.

The anemometers now in use for meteorological observations only register the velocity of the wind, that being sufficient for the purpose of that science. We, as engineers, have taken these recorded velocities, and by means of the table before mentioned, determined the pressures we have thought it necessary to provide against. Moreover, we have considered the maximum velocities recorded at these meteorological stations as the maximum velocities against which it was necessary to provide.

Now, these stations are usually located at isolated and elevated points, and the observations aim to get the velocities of the general currents in motion over extended territories, rather than the level ones most important for engineering purposes. That a general wind current moving over the country at a velocity of say 20 miles per hour, would develop local currents of much greater velocity when the current is contracted by means of gorges, ravines or the high banks of rivers, seems very probable. At such points are frequently located our most important structures, and to what extent such a current may be increased in velocity by being thus confined, is very important for us to know, and it would be interesting to have comparative observations made upon such general currents and the same contracted by neighboring gorges.

During the existence of a prevailing wind it is not supposable that its velocity suddenly changes; but, due to its deflections, we experience an ever changing velocity, passing from the maximum to a dead calm, and frequently, by the rhythmic action of the deflections, we have recurrent gusts or impulses which repeat themselves almost regularly. These would produce upon many of our structures an effect much greater than that due to the same current applied steadily, did it happen that the period of recurrence of these gusts corresponded to the period of oscillation of the structures, for the effect would then be accumulative.

When considering the deflection of a wind current, the up-lifting or down-pressing action of the wind is readily understood. The wind seldom moves in horizontal lines, and it is as important frequently to consider the oblique, as the horizontal action of the wind.

In addition to the want of a proper knowledge of the relation between wind pressure and velocity, and of the maximum velocities of local currents, our knowledge is very limited in regard to the relative effects on different sized or shaped surfaces, and to what extent one surface can form a lee for another placed behind it. Will the resistance offered by a plane surface be the same as a surface of the same area with ribs or projections upon it? How will the resistance of a grated or latticed surface compare with a plane surface? How close must one plate be to another in front of it to be exempt from any additional resistance? And how far off, compared to their size, must they be to get equal resistances? The importance of this knowledge is evident when we see that it may, possibly, quadruple the surface usually considered as affected by the wind pressure. It has been suggested that General Myer, Chief of the Signal Service, would have facilities for making many or all of the desired investigations, and a proper representation by this Society of the needs of engineers in regard to this subject, would have great influence in bringing him to consider the matter. Would it not be well to discuss among ourselves the proper class of experiments desired, and how they could be made with the least expense, and then lay the matter before him for his consideration?

James B. Eads.—I think, upon this subject, there is one point that has not been touched upon, which is very important. It has been generally assumed that wind pressure should be taken as 30 to 50 pounds to the square foot in this country, without reference to the height of the bridges. Now the velocity must be very much greater as you get away from the earth, and consequently a pressure which may be safe at 50 pounds to the square foot within 100 feet, or even 50 feet above the surface of the ground, is not safe when you get 100 or 200 feet above the surface. That is a matter engineers should take into consideration in providing for wind pressure. I do not remember ever having seen attention called to that point. It strikes me as a very important point. Of course that is with reference to resistance to gales and hurricanes, as tornadoes sometimes exert such enormous force close to the earth. It may be stated that their action is limited generally to a very small space, and where it is not possible, or where it is not proper to incur expense in providing against such tornadoes as lifted a locomotive off the track near the eastern end of the St. Louis bridge, you may safely assume that the

chances of tornadoes striking a bridge are infinitely small. The tornado there absolutely lifted the locomotive off the rails, on the leeward side of the locomotive, which of course would have been started by the flanges of the wheels if it had not been lifted; they were undisturbed and the locomotive was thrown over into a ditch or depression some six feet lower than the rails. Col. Flad, and some other gentlemen engaged with me at the time when the St. Louis bridge was being built, made an examination of it.

C. Shaler Smith.—I may state, in reference to tornadoes and their limited area, that I recently went over the track of the Marshfield tornado in this State with Prof. Nipher. We struck into the track of the tornado and he followed it back to where it commenced, while I followed it forty-six miles till it left the ground. The track of the tornado was about 1 800 feet wide clear, leaving the ground at no point in this forty-six miles. It developed at one place a lifting power of 58 pounds per square foot. I found no place where I could get an accurate measurement of its horizontal force. You can judge of its vertical force from the fact that it lifted a piano and moved it 270 feet, and placed it on its feet again without any serious detriment to the piano, while of the house from which it was taken, built with a 13-inch wall, a five room house—one of these large country places—no brick was left standing two feet from the ground. That I think is the widest tornado belt I know of. That at St. Charles was, I think, not more than about sixty feet wide; it developed at one point a lifting power of 85 pounds to the square foot. Its course was very irregular. The central point of this column swung to and fro over a space of 2 000 feet. As it moved from the southwest to the northeast, that tornado passed through the center span of the St. Charles bridge, taking up a barrel of tar that stood in the middle of the bridge, bursting the barrel all to pieces and smearing the tar all round the posts. The only thing that saved the bridge was the narrowness of the column. If it had covered 200 feet instead of sixty it would have carried away the west span. The same storm destroyed the St. Charles jail, damaged the court house and a large brick house. Afterwards I noticed that wherever the tornado passed over a house, the walls of the house as a general thing fell out, with the exception possibly of the gable end,

showing that there was a vacuum and it was the expansion of the internal air that produced the destruction.

Robert Briggs.—However unprepared I may be to speak upon the action of wind upon the Tay Bridge, this question of the tornado and its causes is something of which I can speak. The conditions of the atmosphere that establish a tornado are exceedingly simple. First, There is required nearly an absolute calm—a cessation of wind from all directions; that it shall be a clear day in summer, when the rays of the sun shall be effective in imparting heat to the surface of the ground which shall be communicated to the stratum of air immediately in contact with the ground. Under these conditions the lower stratum of air becomes in very unstable equilibrium, as it will underlie the great mass of the atmosphere through which the sun's rays will have passed without heating or expanding the same in the passage. The lower stratum of light air is therefore compressed by a layer of more dense air uniformly distributed upon its surface, and its effort to rise is resisted by this layer, and by the adhesion of the air to the surface of the earth. In the conditions of quiet supposed, the tendency of the heated air to rise is purely a vertical one. Having supposed or rather having established the foregoing status of equilibrium over a considerable extent of territory, a vertical movement must (in the absence of some sufficient cause for a general horizontal current over the entire territory) eventually disturb it, and at some point more or less central to the heated stratum, an ascending current will generate, slowly at first, but increasing in velocity as the compressed stratum supplies air from all directions with accelerating force towards the vacuity occasioned by continued upward flow. Once commenced, the flow of ascending current will be reinforced and maintained in the one locality (unless other causes intervene) until the entire heated stratum is displaced by normal air, during which displacement or substitution there will exist upon the surface of the ground a rush of air from every quarter, directed to a common center. If the rates of flow from all quarters were altogether uniform, and if the directions of flow were to a common center, the result at the center of action would merely make an inverted funnel of air with a fixed axis or position—a column of air moving directly upwards at high velocity, which column would have the contour due to the least resistance of the particles of air in changing their direction from that of horizontal flow parallel to a plane

surface, to that of vertical flow parallel or nearly so to a vertical axis. The dimensions of such a column are dependent upon the velocity and volume of the air, and the contour would be that of the *vena contracta.*

The flow of horizontal currents towards a common center is, however, one of very unstable equilibrium. Some disturbing influence always directs this flow upon one or the other side of the central axis, and the currents move inward on a tangential path, establishing a whirlwind. The interior of the inverted-conoid-form of the column in contact with the earth, in place of being composed of air under the compression due to the velocity of the winds from all sides, actually has a vacuity caused by the centrifugal action of the whirling currents, and the external dimension of this conoid (or its diameter on any given plane) is much increased by this action.

This proposition can be comprehended by observation of the efflux of water from a common wash-basin with drain plug, or from any vessel for the discharge of water with orifice at the bottom. The formation of the whirlpool, the depression of the level of the water surface due to centrifugal action and to a change of direction of the currents from the horizontal to the downward direction, can be at once seen. In fact in the case of discharge under some conditions of form, we can get a hollow tube of water instead of a solid stream, the vacuity arising from the efflux being carried downward.

The actual pressure of air, or more properly vacuum, from a tornado is not great. The pressure stated by the gentleman preceding me did not exceed 58 pounds to the square foot, only $\frac{4}{10}$ths of a pound per square inch. Comparing this with the pressure of the atmosphere or 14.7 pounds per square inch, the vacuity appears very small. The second tornado pressure quoted was only 85 pounds per square foot, or $\frac{6}{10}$ths of a pound per square inch. Even this is a very small part of an absolute vacuum. These pressures of 58 and of 85 pounds are, I suppose, deduced values from some movement of some object, but it is proper to state that they are probably very much under the actual pressures existing if not exerted. It is only needful to consider that the atmospheric pressure in ordinary conditions is 2 117 pounds per square foot to appreciate that there exists what the newspaper reporters call an "irresistible force" in the disturbance of that pressure.

The locality of the axis of any vortex or tornado is not necessarily, in fact is never, a fixed one, but it will be found to have a path or direction

often tortuous from local influences or obstructions, but generally following some sweep of curvature of great radius, rather than a straight or sinuous line. It is very possible that in places favorable to the repetition of tornado storms, their paths will be found to have some usual direction that will allow a probable course to be asserted as the path after commencement. The phenomena of a tornado or a whirlwind are thus seen to be by no means incompatible with the well understood physical properties of the atmosphere.

The most remarkable tornado, the results of which I have had the opportunity of observing personally, was one that occurred in 1850 or 1851, at Medford, near Boston. This tornado had a course in its entire length of about 13 miles. The path of its center or nucleus of absolute devastation was only about 18 feet wide. The general path of this tornado was a comparatively straight line for two or three miles, although the track itself was extremely tortuous. It was in a country of stone walls and of boulder rocks. There were houses and trees in the course of its track. The stones, the walls, the trees, the houses were completely swept away or displaced.

It is in similar limited tracts that any tornado exerts its force.

I wish it to be thoroughly appreciated that there is no mystery about the formation of a tornado; it is merely the result of an unstable equilibrium that exists from the levity of air on the surface of the ground when there is general quiescence of the atmosphere.

Our hail storms and sudden summer showers have similar origin. The levity of our summer air arises not alone from heat but in part from the moisture present. With the presence of water surfaces and of vegetation, the proportion of moisture at our high temperature for summer becomes large. In the case of the hail storm or summer shower, it is the condensation of this moisture which supplies the hail or the rain precipitated. The same conditions of levity of air upon the surface as have been described for the tornado, will have established a less intense and possibly more voluminous local upward current of air. At the height of three miles—only three miles away—this current must have been rarefied and expanded to the point of not only condensation but of frigeration of all the moisture present. It is only necessary that there should be a gust of air from the ground upwards to this height, to make all the conditions for a hail storm on any summer day.

One of the providential things in the falling of hail stones, is that

they generally descend against a violent upward current of air, and are thereby deprived of the high velocity which such masses would attain in still air or in air in horizontal movement.

It must not even be admitted that these propositions as to the results of vertical currents of air relate alone to tornadoes or hail storms. In all cases and at all times, a rain storm may be taken as an indication of an ascending current of air; slowly ascending perhaps, but still ascending until some point of elevation is reached where the moisture present is incompatible with the temperature and pressure of the air. At five miles height the air is nearly anhydrous.

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INSTITUTED 1852.

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CCVIII.

(Vol. IX.—October, 1880.)

CHEAP TRANSPORTATION VS. RAPID TRANSIT AND DELIVERY.

By MARTIN CORYELL, Member of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, MAY 25TH, 1880.

To open the subject of the proposed paper, it will be assumed that the productions of our country, and the manufactures, began to assume commercial importance about the year A. D. 1800.

The ocean, bays and rivers then formed the cheap transportation lines for commerce and travel; and, as a consequence, the largest cities, towns and trade centers were on navigable waters.

As the country increased in population, and agriculture advanced, and manufactures prospered, yielding a surplus above the wants of the producer, centers of trade and exchange were established in the interior of the country, and such towns as Worcester in Massachusetts, Albany and Schenectady in New York, Lancaster and Reading in Pennsylvania, Frederick in Maryland, Charlotte and Lynchburg in Virginia, were established, and were connected by roads with the cities on the navigable waters.

Then came the necessity for turnpikes, to cheapen, or rather to hasten, transportation; they were such a success over the common roads that the leading "Turnpikes" became over-burdened, and were nearly destroyed by the traffic they had to carry, and in connection with oppo-

sition and competing lines the tolls could scarcely keep them in repairs, and no dividends accrued for the original stockholders.

The great "National Road" or turnpike of the United States Government is familiar to older members.

The capital invested in turnpikes failed to be profitable. Yet the cities and the country adjacent to them profited greatly by their construction.

The next effort to meet the wants of a growing commerce, and to convey large amounts cheaply, was by the means of canals; and the completion of the Erie Canal established an era in canalling which pervaded the States of our Union, and many States plunged recklessly and —for that day—fearfully into debt to construct cheap transportation lines.

Of the many canals projected, and some completed, only a few remain that are useful to the country, and they are scarcely profitable after renewals, repairs and expenses are paid.

For about fifteen years canals seemed to be a favorite mode of transportation, and shares of stock were held above par; and water-fronts, accessible to canal boats and shipping, commanded fabulous rents; and merchandise, coal and lumber were piled from twenty to forty feet in height on the wharves.

With the canals, and the increase of trade and commerce they effected, were developed the difficulties and expenses of terminal facilities; and so great and so inconvenient were they that railroads became a relief, and actually grew into favor, to the detriment of canals and water-fronts.

The Philadelphia, Reading and Pottsville Railroad, the Hudson River Railroad, the Philadelphia Wilmington, and Baltimore, and the Baltimore and Ohio Railroads became the early antagonists of canal, river and bay navigation.

Many of us can remember how learnedly the late Charles Ellett proved that within a very few years the Reading Railroad would have to give way to the Schuylkill Canal. It would be abandoned, and the canal would be carrying the freight so cheaply that the railroad could not be maintained.

When some bold capitalists, with our venerable and esteemed Honorary member John B. Jervis, as their engineer, projected and estimated the cost of a railroad along the Hudson river, and the estimated amount of traffic and travel there would be to sustain it, many can re-

call the contempt and scorn with which canal engineers and vessel owners treated the subject, and thought it preposterous to entertain for a moment the possibility of a railroad contending with the free navigation of such a noble and magnificent river as the Hudson, with a capacity to accommodate the tonnage of the United States, and with floating palaces for the transmission of passengers to the number of a thousand or more at a time, at a speed of sixteen miles per hour.

The Camden and Amboy route, between New York and Philadelphia, consisting of thirty miles of steamboat travel to Amboy, twenty-eight miles of railroad to Bordentown, then twenty-six miles by steamboat down the Delaware to Philadelphia, has so long been abandoned for a through rail route, that it is almost forgotten.

So with the water route from Philadelphia to Baltimore, viz.: By steamboat down the Delaware river, forty miles, to Newcastle; then by rail fourteen miles, across the State of Delaware to Frenchtown; then by steamboat, on the Chesapeake Bay, about fifty miles, to Baltimore.

The Philadelphia, Wilmington and Baltimore through rail route used up this cheap and pleasant mode of transportation and travel.

These are a few leading instances in which water routes, giving cheap transportation to travel and commerce, had to yield to railroad lines.

No reference need be made to the rivers of the West and the great lakes, for the subject is familiar to all who have to do with commerce, travel and transportation.

The cities on tidal waters, Western rivers and lakes, have to avail themselves of railroad facilities of the most costly character, to maintain their commercial importance, and capital is most lavishly expended to secure this object.

Other competing elements to cheap transportation by water routes are the telegraph and telephone lines.

Cheap transportation by water in this country has not been, and cannot be, more than a temporary success. What has been done, and what now remains, has accomplished the mission intended, viz., an advancing step in the improvements and growth of our country and commerce.

All such routes have been virtually retired from the scene of competition and rivalry of the railroads.

The Suez Canal is put forward as a grand accomplishment in facilitating commerce, and so it is, and is deserving of all the honor and praise bestowed upon it and its projectors and engineers that executed the

work; and yet, within forty years or less, its commercial value will be rendered almost worthless by competing rail routes from India to England and France, by way of the Dardanelles and roads on either side of the Red Sea to the Mediterranean.

The wants of the day are rapid transit and quick delivery, and if that can be accomplished, cheap transportation must yield, and commerce can well afford, and will always cheerfully pay the difference of cost.

The commercial enterprise and knowledge of the laws and requirements of trade, which have of late years been incorporated in the management of large railroad enterprises, have made wonderful changes and necessities, that are far in advance of the conceptions and ideas of the law-makers and engineers of forty years ago.

Then, railroad charters gave a length of from 30 to 300 miles for the road, with the limit of about an acre of ground in the cities for terminal purposes, and the capital was about $30 000 per mile of road.

At the present time the extent of the leading railroad lines is so great, and the amount of capital invested is so enormous, that *Poor's Manual* of railroads has to be referred to for information.

Terminal facilities, rapid handling of freights, and no delays in transit, are now engrossing the attention of railroad officials, and the demand for expedition in the handling of grain and coal by the aid of steam machinery, through the grain elevators, and over coal trestles, the transportation and storage of oil, etc., is made evident from the costly structures that are found at all points, connecting rail transportation with shipping, or receiving and storing depots.

All goods in large amounts must be handled promptly and in good order, and machinery and facilities must be provided for so doing.

Some years ago the idea prevailed that large vessels would cheapen transportation.

The *Great Eastern* steamship was constructed in England, and Donald McKay, of Boston, built the large sailing vessel, *The Great Republic*, and there was a very large vessel constructed, to fill the area of the double or enlarged locks of the Delaware and Raritan Canal, to ply between New York and Philadelphia.

So much time and labor was required to discharge cargoes, to reload, distribute and secure freight, that the wharfage, demurrage and daily expenses whilst laying at their berths, completely absorbed all profits;

and that they were not a success may be inferred from the fact that no other vessels of this large class have been constructed since.

Commercial countries that are separated from each other by the oceans do not require immense ships, but of a size and speed that can make quick trips, and can enter ordinary rivers and harbors.

One large city, or one country, cannot monopolize the ocean commerce of the world.

The lading the largest vessels can carry must be distributed to manufacturers, or the people who consume or use, and they are not all on the shore of one great city that the ships can reach; therefore, the more numerous the commercial ports, the greater the opportunity to distribute the lading of the ships to the points required.

By examining the net work of railroads of this country and their power of rapid distribution of merchandise, we must be convinced that railroads do most essentially fulfill that duty, and make every section of our country important to commerce and trade.

Continental lines of railroads and telegraphs across the continent, from ocean to ocean, completed, under construction and projected, will take up and distribute all the lading the shipping may find to convey across either ocean.

If through freight, it will be carried so quickly that the extra cost of handling will be fully compensated for in time saved.

The members of this Society are fully cognizant of the several proposed canal routes across or through the continent, at or near Darien.

The instructive maps that have been exhibited, and the able papers which have been read, discussed, printed and circulated, prove the interest manifested in the proposed work, and the more the subject is investigated, the estimated cost of construction increases, and the estimated revenue decreases.

The experience had in this country is against canals.

It is not to be supposed that commerce can be diverted so far out of direct routes, merely to enjoy a great deal of cheap transportation and the pleasure of passing slowly through a lake, with locks for ingress and egress and very bad harbors, or a canal without locks, with a thorough cut through the Cordilleras, and a voluminous river, with often a hydrostatic pressure of sixty feet altitude threatening to work devastation to the canal and all that may be within it, and with a harbor on the Atlantic side much exposed.

Perhaps, through a tidal canal, with safe harbors on each ocean and a tunnel of seven miles in length ; or by another projected scheme, with an artificial lake made by constructing a dam eighty feet in height, and reaching the proposed lake by four locks of twenty feet lift each, and leaving it by the same number of locks, and steam to do the work of opening and closing the lock gates, and taking vessels in and out of the locks.

An enterprising Quaker citizen of Philadelphia, Josiah White, publicly made the expression, "that rivers were made to be dammed," and through the influence of his moneyed friends, he was furnished with the means of placing dams in the Lehigh river, from twenty to over fifty feet in height.

For a time they were a success, but the guard banks settled and were worn down, the exposed wood work became decayed, and an extraordinary flood, "peculiar to American rivers" (as stated by Mr. Welch), came, and all but three of these pools created by the high dams and embankments were washed out and emptied, causing sad destruction of property and loss of life.

The high dams were not rebuilt, neither was the slack water navigation renewed, but a railroad was substituted.

Captain Eads, whose success in establishing and maintaining a ship channel at the mouth of the Mississippi has established for himself a reputation that is widely respected, and he proposes to supplant the Isthmian Canal by a scheme to convey ships from ocean to ocean by railroad.

Canals, and improvements of water-courses to a limited extent for commercial purposes, when judicially planned, are appropriate and proper.

When schemes, as a canal to unite the Ohio river with the Atlantic ocean, the lakes with the Mississippi river, a canal around Niagara Falls, or a canal to connect the Atlantic with the Pacific ocean, are advocated, it is an evidence that the advantages of railroads over canals, for profitable and successful transportation, are not fully comprehended.

The wonderful progress and success in bridge building, and the power and speed of the locomotive, have placed railroads and rail transportation far in advance of canals, and the canals, wherever located, simply supply a connecting link between the past and the present.

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CCIX.

(Vol. IX.—October, 1880.)

THE CRIPPLING STRENGTH OF WROUGHT IRON COLUMNS.

By C. L. GATES, JUNIOR of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, MAY 25TH, 1880.

From experiments made by G. Bouscaren, C. E., and from former tests of his own upon wrought iron columns, C. Shaler Smith, C. E., devised formulæ applicable to the several forms in use, approximating quite closely to the results of their experiments in most instances. These formulæ were adopted by the Engineer Department of the Chicago, Milwaukee and St. Paul Railway several years ago, and since their publication have been quite extensively used in specifications of works throughout the country and somewhat abroad.

The purpose of this paper is to present them to the Society in such shape as to invite criticism as to their correctness.

Said formulæ herewith given, show the ultimate crippling strength in pounds per square inch of section of the several forms of posts, H. representing the length between end bearings in terms of the least diameter.

From these formulæ I prepared tables for ultimate crippling strength for the various columns from 15 to 60 diameters long, which are here given in tables I., II. and III.

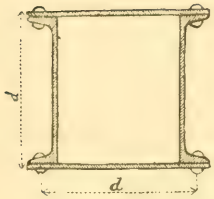
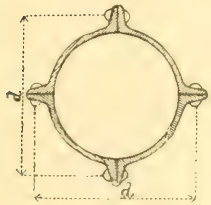
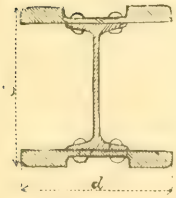
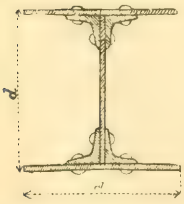
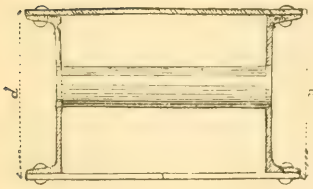
	Flat Ends.	One Pin End.	Two Pin Ends.
	SQUARE COLUMN.		
	$\frac{38,500}{1+\frac{H^2}{5820}}$	$\frac{38,500}{1+\frac{H^2}{3000}}$	$\frac{37,500}{1+\frac{H^2}{1900}}$
	PHŒNIX COLUMN.		
	$\frac{42,500}{1+\frac{H^2}{4500}}$	$\frac{40,000}{1+\frac{H^2}{2250}}$	$\frac{36,600}{1+\frac{H^2}{1500}}$
	AMERICAN COLUMN.		
	$\frac{36,500}{1+\frac{H^2}{3750}}$	$\frac{36,500}{1+\frac{H^2}{2250}}$	$\frac{36,500}{1+\frac{H^2}{1750}}$
	COMMON COLUMN.		
	$\frac{36,500}{1+\frac{H^2}{2700}}$	$\frac{36,500}{1+\frac{H^2}{1500}}$	$\frac{36,500}{1+\frac{H^2}{1200}}$
	COMMON CHORD SECTION.		
	The pin being so placed that the moment of inertia is, as near as practicable, equal on both sides of same, use formulæ for square column.		

TABLE I.

Ultimate Crippling Strength per Square Inch of Columns with Flat End Bearings.

H= LENGTH OF COLUMN IN TERMS OF LEAST DIAMETER.	SQUARE COLUMN.	PHŒNIX COLUMN.	AMERICAN COLUMN.	COMMON COLUMN.
15	37 067	40 476	34 434	33 693
16	36 876	40 212	34 167	33 339
17	36 679	39 935	33 888	32 971
18	36 470	39 645	33 597	32 589
19	36 252	39 343	33 294	32 195
20	36 024	39 030	32 982	31 790
21	35 785	38 706	32 659	31 375
22	35 544	38 373	32 327	30 952
23	35 292	38 029	31 987	30 520
24	35 033	37 677	31 640	30 082
25	34 767	37 317	31 285	29 639
26	34 492	36 949	30 925	29 191
27	34 212	36 575	30 559	28 740
28	33 929	36 192	30 188	28 286
29	33 639	35 807	29 813	27 831
30	33 344	35 424	29 435	27 375
31	33 044	35 021	29 054	26 919
32	32 740	34 621	28 671	26 463
33	32 431	34 219	28 285	26 010
34	32 120	33 813	27 899	25 557
35	31 806	33 406	27 512	25 108
40	30 198	31 352	25 584	22 919
45	28 562	29 310	23 701	20 857
50	26 932	27 321	21 900	18 952
55	25 333	25 415	20 203	17 214
60	23 787	23 611	18 621	15 643

TABLE II.

Ultimate Crippling Strength of Columns with one Pin End.

H=LENGTH OF COLUMN IN TERMS OF LEAST DIAMETER.	SQUARE COLUMN.	PHŒNIX COLUMN.	AMERICAN COLUMN.	COMMON COLUMN.
15	35 814	36 364	33 182	31 739
18	34 748	34 957	31 898	30 016
20	33 971	33 962	30 991	28 815
21	33 566	33 445	30 518	28 207
22	33 152	32 919	30 038	27 596
23	32 729	32 386	29 552	26 984
24	32 299	31 847	29 061	26 373
25	31 862	31 304	28 565	25 765
26	31 420	30 759	28 067	25 161
27	30 973	30 212	27 568	24 563
28	30 523	29 664	27 068	23 971
29	30 070	29 117	26 569	23 387
30	29 615	28 571	26 071	22 812
31	29 153	28 029	25 576	22 247
32	28 703	27 489	25 084	21 692
33	28 246	26 948	24 590	21 147
34	27 794	26 424	24 112	20 614
35	27 337	25 899	23 633	20 092
36	26 885	25 381	23 160	19 582
37	26 424	24 869	22 693	19 083
38	25 990	24 364	22 232	18 597
39	25 547	23 866	21 778	18 123
40	25 109	23 377	21 331	17 661
45	22 985	21 053	19 210	15 532
50	21 005	18 947	17 290	13 688
55	19 170	17 062	15 569	12 100
60	17 500	15 349	14 038	10 737

TABLE III.

Ultimate Crippling Strength of Columns with Two Pin Ends.

H=LENGTH OF COLUMN IN TERMS OF LEAST DIAMETER.	SQUARE COLUMN.	PHŒNIX COLUMN.	AMERICAN COLUMN.	COMMON COLUMN.
15	33 798	31 825	32 342	30 666
20	31 226	28 894	29 709	27 375
21	30 679	28 283	29 153	26 691
22	30 126	27 670	28 592	26 010
23	29 568	27 057	28 028	25 333
24	29 007	26 444	27 462	24 662
25	28 444	25 834	26 895	24 000
26	27 880	25 229	26 329	23 348
27	27 318	24 629	25 766	22 706
28	26 759	24 036	25 210	22 077
29	26 202	23 451	24 653	21 460
30	25 650	22 874	24 104	20 857
31	25 103	22 307	23 561	20 268
32	24 561	21 750	23 026	19 694
33	24 028	21 204	22 499	19 135
34	23 501	20 669	21 980	18 591
35	22 982	20 146	21 471	18 062
36	22 472	19 635	20 970	17 548
37	21 970	19 135	20 479	17 050
38	21 477	18 647	19 999	16 566
39	20 994	18 172	19 528	16 097
40	20 520	17 709	19 067	15 643
45	18 298	15 574	16 920	13 581
50	16 326	13 724	15 029	11 838
55	14 583	12 132	13 377	10 367
60	13 058	10 766	11 939	9 125

Plate XXII. is a graphic representation of the strength of these columns in which the abscissa represents length of columns and the ordinates strength.

From the fact that in all built columns the liability of imperfections increases to some extent with the length of the column, a sliding factor of safety is introduced.

The following tables have been calculated, using a factor of safety of $4 + 0.05\,H$.

TABLE IV.

SAFE CRIPPLING STRAINS. COLUMNS WITH FLAT ENDS.

H = LENGTH OF COLUMNS.	SQUARE COLUMN.	PHŒNIX COLUMN.	AMERICAN COLUMN.	COMMON COLUMN.
15	7 822	8 521	7 249	7 093
16	7 683	8 377	7 118	6 946
17	7 563	8 234	6 987	6 798
18	7 443	8 091	6 856	6 651
19	7 324	7 948	6 726	6 504
20	7 205	7 806	6 596	6 358
21	7 087	7 665	6 467	6 213
22	6 970	7 524	6 338	6 069
23	6 853	7 384	6 211	5 926
24	6 737	7 245	6 084	5 785
25	6 622	7 110	5 959	5 646
26	6 508	6 971	5 835	5 508
27	6 396	6 836	5 712	5 372
28	6 284	6 702	5 590	5 238
29	6 173	6 570	5 471	5 107
30	6 063	6 440	5 352	4 977
31	5 954	6 310	5 235	4 850
32	5 846	6 182	5 119	4 726
33	5 740	6 056	5 006	4 604
34	5 635	5 933	4 894	4 483
35	5 531	5 810	4 789	4 367
40	5 033	5 226	4 264	3 820
45	4 570	4 690	3 792	3 337
50	4 143	4 203	3 369	2 916
55	3 728	3 765	3 004	2 550
60	3 398	3 373	2 660	2 235

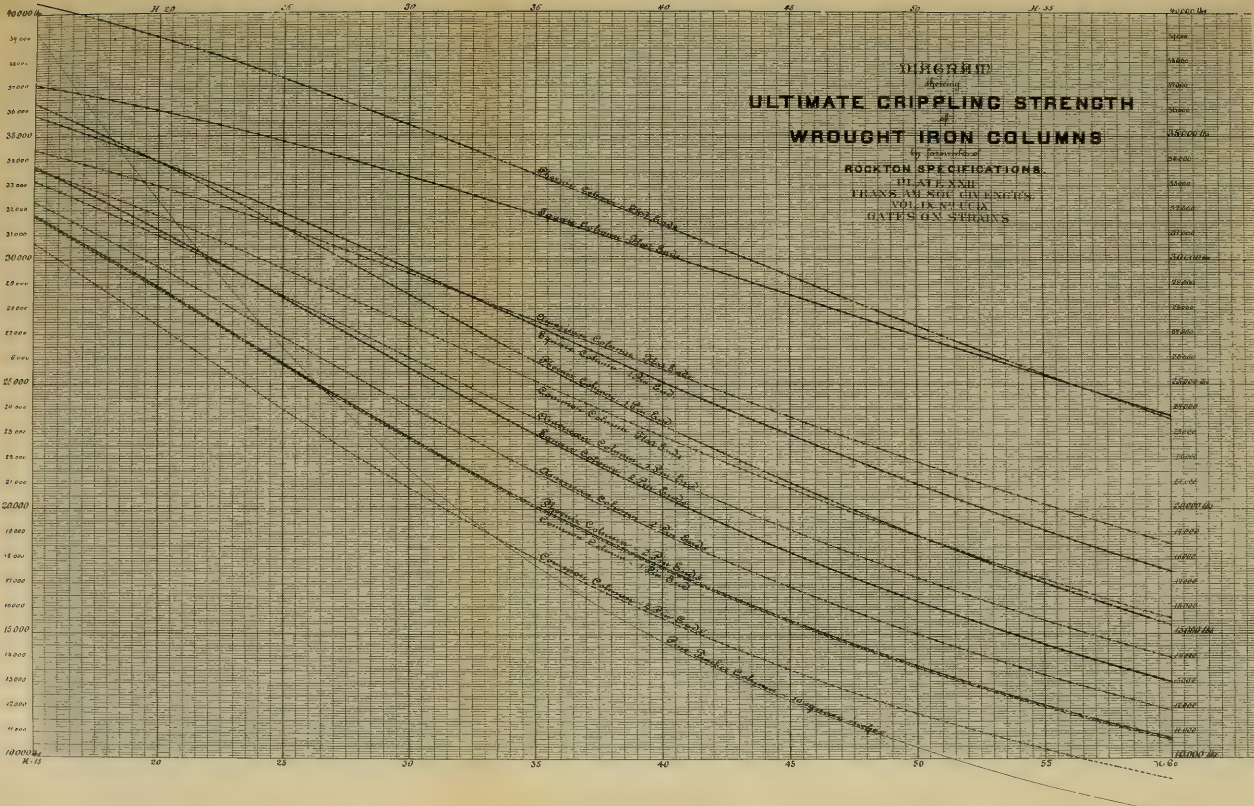


DIAGRAM
showing
ULTIMATE CRIPPLING STRENGTH
of
WROUGHT IRON COLUMNS
by formulas of
ROCKTON SPECIFICATIONS.
PLATE XXII
TRANS. AM. SOC. CIV. ENG'RS.
VOL. IX. Nº CLXIX
GATES ON STRAINS

TABLE V.

Safe Crippling Strains. Columns with One Pin End.

H=LENGTH OF COLUMN.	SQUARE COLUMN.	PHŒNIX COLUMN.	AMERICAN COLUMN.	COMMON COLUMN.
15	7 540	7 656	6 986	6 682
18	7 091	7 134	6 510	6 126
20	6 794	6 793	6 198	5 763
21	6 647	6 623	6 043	5 586
22	6 500	6 455	5 890	5 411
23	6 355	6 289	5 738	5 240
24	6 211	6 125	5 589	5 072
25	6 069	5 963	5 441	4 908
26	5 928	5 804	5 296	4 747
27	5 789	5 647	5 153	4 591
28	5 652	5 493	5 013	4 439
29	5 518	5 343	4 875	4 291
30	5 385	5 195	4 740	4 148
31	5 253	5 050	4 608	4 008
32	5 125	4 909	4 479	3 874
33	4 999	4 770	4 352	3 742
34	4 875	4 636	4 230	3 616
35	4 754	4 504	4 110	3 494
36	4 635	4 377	3 993	3 376
37	4 519	4 251	3 879	3 262
38	4 405	4 129	3 768	3 152
39	4 294	4 011	3 660	3 046
40	4 185	3 896	3 555	2 944
45	3 678	3 368	3 074	2 485
50	3 232	2 915	2 660	2 106
55	2 840	2 528	2 307	1 793
60	2 500	2 198	2 006	1 534

TABLE VI.

SAFE CRIPPLING STRAINS. COLUMNS WITH TWO PIN ENDS.

H = LENGTH OF COLUMN IN TERMS OF LEAST DIAMETER.	SQUARE COLUMN.	PHŒNIX COLUMN.	AMERICAN COLUMN.	COMMON COLUMN.
15	7 115	6 700	6 809	6 471
20	6 245	5 779	5 942	5 475
21	6 075	5 601	5 773	5 285
22	5 907	5 425	5 608	5 100
23	5 741	5 254	5 442	4 919
24	5 578	5 085	5 281	4 743
25	5 418	4 921	5 123	4 572
26	5 261	4 760	4 968	4 405
27	5 106	4 604	4 816	4 245
28	4 955	4 451	4 668	4 088
29	4 807	4 303	4 524	3 938
30	4 664	4 159	4 383	3 792
31	4 523	4 019	4 245	3 652
32	4 386	3 884	4 112	3 517
33	4 253	3 753	3 982	3 387
34	4 123	3 626	3 856	3 262
35	3 997	3 504	3 734	3 141
36	3 875	3 386	3 616	3 026
37	3 756	3 271	3 501	2 915
38	3 640	3 161	3 390	2 808
39	3 529	3 054	3 282	2 705
40	3 420	2 952	3 178	2 607
45	2 928	2 492	2 707	2 173
50	2 512	2 111	2 312	1 821
55	2 160	1 797	1 982	1 536
60	1 866	1 538	1 706	1 304

Diagrams, as before constructed, are added, representing graphically actual compressive strains permitted on wrought iron columns as per given formulæ. (See Plate XXIII.)

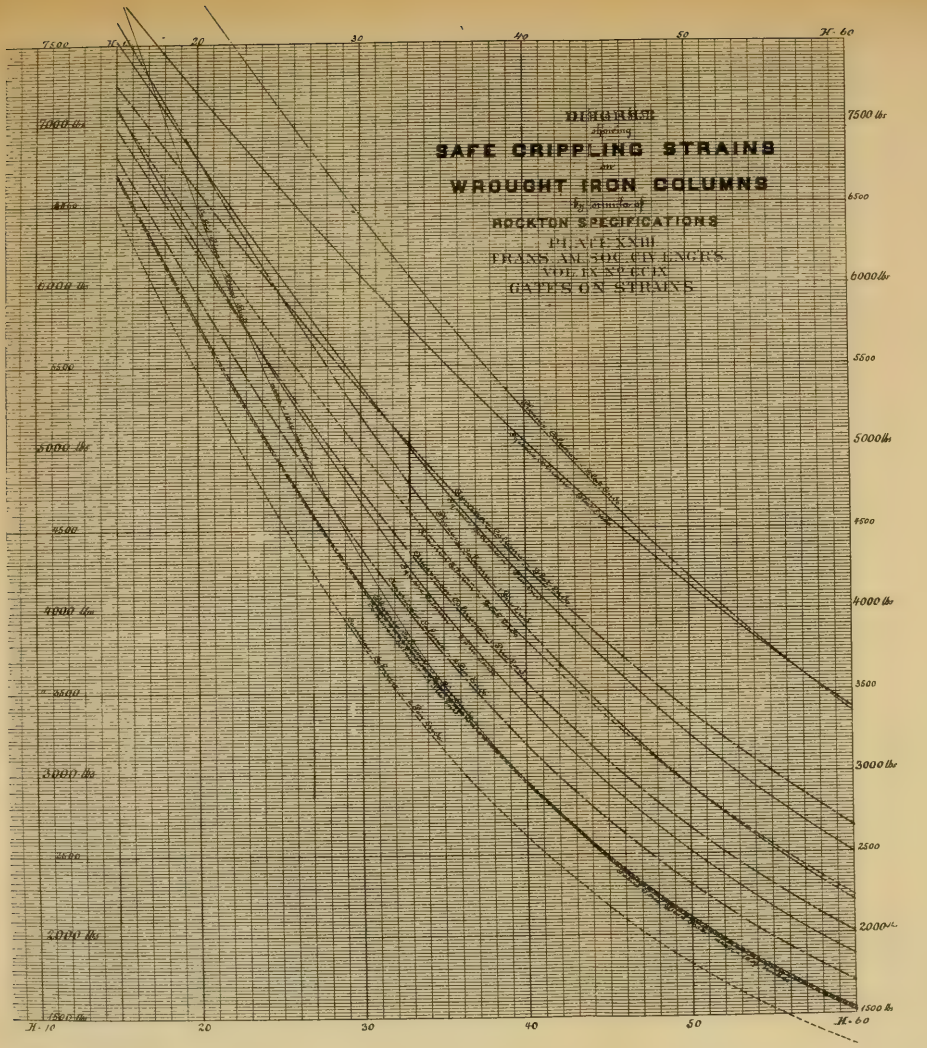


DIAGRAM
showing
SAFE CRIPPLING STRAINS
in
WROUGHT IRON COLUMNS
by formula of
ROCKTON SPECIFICATIONS
PLATE XXIII
TRANS. AM. SOC. CIV. ENGRS.
VOL. IX. No. CCIX
GATES ON STRAINS
H-10
20
30
40
50
H-60
7500 lbs
6500
6000 lbs
5500
5000 lbs
4500
4000 lbs
3500
3000 lbs
2500
2000 lbs
1500 lbs

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCX.

(Vol. IX.—November, 1880.)

WEB STRAINS IN SIMPLE TRUSSES WITH PARALLEL OR INCLINED BOOMS.

By ELNATHAN SWEET, JR., Member of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, 25TH MAY 1880.

The great number of elaborate contributions which technical literature has in late years received upon the general subject of framed structures, makes the idea of throwing new light upon, or investing with greater simplicity the branch under consideration within the limits of a brief paper, appear at first glance idle and presumptuous.

The great number and universal distribution of the structures embraced in the classification to which this discussion is directed, and the fact that the great part of the handbooks and treatises on this subject give solutions of this class of frames based on a false assumption, and,

so far as I know, all fail in attaining the desired directness and simplicity in their treatment may, however, be plead in justification. Upon these handbooks the great body of practical engineers are obliged to rely, for the want of time and opportunity for investigation, though often called upon to design street and highway bridges of moderate spans.

This reliance results in strain sheets which are invariably inaccurate as to the web members, and never approximately correct in the case of bowstring girders.

The ordinary method of determining the maximum effect of the moving load upon the web members of simple as well as of compound trusses, assumes that as the moving load passes over them each panel is fully loaded before the adjacent triangle in advance bears any part of the load.

In trusses with a single system of triangulation or those in which the web strains of any panel pass to the abutment through the web members of the adjacent panel, this assumption is obviously erroneous, for the instant the head of the load passes a panel joint of such a truss a part of it is transmitted by the floor system to the adjacent triangle of the same system.

With this fact in view, we may proceed to investigate the maximum vertical stresses produced by uniform moving loads in trusses of this class.

The simplicity of mathematical formulæ and their ready adaptability to practical use, depend in great measure upon the nomenclature through which they are deduced.

In investigating trusses divided into panels of equal length, the panel length is the most simple and natural unit of length.

The strains change only at panel points, we have to deal with panel loads, and if in designing the truss the rise or height and the panel length are made to have a simple numerical ratio, the adoption of the panel length as the linear unit will be found to greatly abridge the arithmetical computations.

In Fig, 1, Plate XXIV., D, E, represents a simple truss, having N equal panels. Then the panel length being the linear unit, $N =$ length of truss.

Let $w =$ the dead load per panel, and $w' =$ the moving load per panel. Let n represent the number and consequent distance of any panel point from the loaded abutment and $h =$ the height of truss.

The bridge has a single system of triangles, and its floor joists are not continuous over the panel points, conditions which subsist in nearly all highway and street bridges of moderate span.

Suppose the moving load to proceed from and cover the part of the truss from D to a point f between the panel points n and $n+1$, measured from abutment D, and represent the portion ef of the panel beyond n, covered by the load by y.

It is required to find the maximum shearing strain at any panel point n due to the uniform moving load w' per panel.

The moment the front of the moving load passes the panel point n, a definite portion is transmitted by the floor joists to the panel point $n+1$, in advance of the load.

The principle that the shearing stress due to a partial load at any point in a beam, is equal to the reaction at the unloaded abutment due to that load, less the portion of the load between the point and that abutment, makes it evident that the shearing stress at n borne by the diagonal n, will increase until the head of the moving load passes the point n, and that it will diminish before the load reaches the point $n+1$.

This principle may be expressed analytically as follows. Let R = the reaction at E from the portion of the moving load between D and n, R' the reaction at that abutment from the portion on y that is between n and f, and let P represent the portion of the load on y, transmitted by the floor system to the panel point $n+1$. Then the shearing stress S_n at $n = R + R' - P$.

The reaction $R = \frac{Wx}{N}$ in which W = the whole load borne by the truss between D and $n = (n - \frac{1}{2})\ w'$ and x = the distance of the centre of gravity of W from D, or the sum of the products of each panel weight by its distance from D, divided by the whole weight $\left(\frac{2n-1}{2}\right) w'$

$$\therefore x = \frac{w' + 2w' + 3w' \ldots + (n-2)w' + (n-1)w' + \frac{n\,w'}{2}}{\frac{(2n-1)w'}{2}}$$

$$= \frac{\frac{n^2 w'}{2}}{\frac{(2n-1)w'}{2}} \qquad \text{but } R = \frac{Wx}{N} = \left(\frac{2n-1}{2N}\right) w' \left(\frac{n^2 w'}{2}\right) = \frac{n^2 w'}{2N.}$$

$$\left(\frac{2n-1.}{2}\right) w'$$

and R' the reaction at E from the load covering the portion y of the panel n to $(n+1)$, since the distance of its centre of gravity from D is $n+\frac{y}{2}$ and its weight $w'\,y$, is $R'=\left(\frac{n\,y+\frac{y^2}{2}}{N}\right)w'$, and P the portion of the moving load on y, which is borne by the panel point $(n+1)$ is $w'\,y\times\frac{y}{2}$ or $P=\frac{w'\,y^2}{2}$.

The reaction at E due to the whole moving load in the position assumed, is therefore $R+R'=\frac{n^2\,w'}{2\,N}+\frac{ny+\frac{y^2}{2}}{N}$, and the weight between the point n, where the shearing stress is sought and the unloaded abutment E is $P\times\frac{w'\,y^2}{2}$. Therefore the shearing stress at n is,

$$S_n=\frac{w'\,n^2}{2\,N}+\frac{ny+\frac{y^2}{2}}{N.}-\frac{w'\,y^2}{2}$$

$$\text{or } S_n=(n^2+2\,ny+y^2-N\,y^2)\frac{w'}{2\,N} \qquad (1).$$

This expression is obviously true for any value of y less than the panel length, and the value of y which renders it a maximum determines the position of the moving load which produces the greatest shear at the point n. We have by differentiation (neglecting the factor $\frac{w'}{2\,N}$ which is independent of y), $\frac{ds}{dy}=2\,n+2\,y-2\,N\,y.$

Making $\frac{ds}{dy}=0.\quad y=\frac{n}{N-1.}$

As the second dif. co-efficient is negative, this value of y renders the above general expression for the shearing strain a maximum.

Substituting this value of y in equation (1) and reducing we find

$$S_n=\frac{n^2\,w'}{2\,(N-1)} \qquad (2).$$

This is the general expression for the maximum shearing stress at any point n of a simple truss due to a uniform moving load w' per panel.

These vertical shearing stresses in framed beams with parallel chords are evidently wholly transmitted by the inclined braces a, b, c, etc., the induced strain being measured by the vertical shear at their end nearest

the loaded abutment, multiplied by the secant of their inclination to the vertical.

The whole stress in these braces, however, depends upon the combined action of the dead and moving load. The former since it is essentially constant and uniform in its action is correctly represented by the usual assumptions and accurately measured by the formulæ in common use.

By the nomenclature we have adopted, we can readily deduce the shear at any point of a simple truss due to the combined effect of the dead and moving load, and the resultant stress in any web member from their combined effect.

The shearing stress S' due to the dead load w with reference to the abutment E, numbering the panel points as before from D, at any point n, is $S'_n = \frac{(N-1)}{2} w - [N-(n+1.)]\ w = \frac{2n-(N-1)}{2} w.$

The greatest stress in any brace transmitting the moving load from n toward the unloaded abutment is therefore

$$(S_n + S'_n)\ sec.\ i = \left(\frac{n^2 w'}{2(N-1)} + \frac{2n-(N-1)\ w}{2}\right) sec.\ i.$$

If the brace be vertical, $sec.\ i = o.$

The solutions of this equation for values of n less than $\frac{N}{2}$ give the counter strains, and for values of n from $\frac{N}{2}$ to $(N-1)$ give the strains on the main ties and braces.

If the chords, as in the bowstring girder are not parallel, the stress in the web is increased or diminished thereby according as they diverge or converge from n toward E, though the principle determining the maximum shearing stress and its amount are not effected. The method of sections offers in this case the simplest analytical solution of the web strains.

If the bowstring $D\ E$ (Fig. 1) be cut by a vertical plane at any point as between n and $n+1$, the theory of equilibrium requires that the horizontal component of the stress in the compression member shall equal the sum of the horizontal components of the stresses in the tensile members.

The section of the arch A is obviously the compression member, and the section of the lower chord B and the diagonal C the tensile members.

If we represent the height of the arch at n by h_n and at $n+1$ by h_n+1, by the principle of the lever we have for the horizontal com-

ponent of the stress in the compression member A, due to the part of the moving load producing the maximum stress in the diagonal, $C =$ the maximum stress $\frac{n^2 w'}{2 (N-1)}$ multiplied by the distance of the point n, from the unloaded abutment $E, = N - n$ divided by h_n, or $= \frac{n^2 w'}{2 (N-1)} \times \frac{N-n}{h_n}$ and the horizontal stress in the section of the lower chord B $= \frac{n^2 w'}{2 (N-1)} \times \frac{N-(n+1)}{h_{n+1}}$.

The horizontal component of the maximum stress in the diagonal C (or n) is, therefore, the difference of these horizontal stresses in A and B, or $= \frac{n^2 w'}{2 (N-1)} \times \left(\frac{N-n}{h_n} - \frac{N-(n+1)}{h_{n+1}} \right)$ (3.)

The value of this expression mutiplied by $\frac{\text{the length of the diagonal}}{\text{the panel length}}$ gives the greatest stress on the diagonal n, due to the moving load.

If the truss be so designed that the panel points of one or both chords lie in the curve of equilibrium for an unbraced arch, the uniform dead load produces no stress in the diagonals.

For this case the above formula (3) can be simplified by deducing the values of h_n and h_{n+1} in terms of the known rise at the centre which we will represent by h.

The condition of equilibrium for the uniformly loaded, unbraced arch requires that the horizontal components of the stresses in all the arch members shall be equal. But the horizontal stress in any member of an arched truss is by the principle of the lever equal to the moment of flexure at its upper extremity divided by the vertical distance from that extremity to the lower chord. Therefore, the heights of the panel points of such a truss must vary as the moments of flexure at these points.

By the nomenclature we have adopted the moment of flexure at any point n, from a uniform load w per panel, is $m_n = \frac{wn}{2}(N-n)$.

The moment at the centre where the height is h, is $\frac{w N^2}{8}$

From the condition of equilibrium we have

$$\frac{w N^2}{8} : \frac{w n}{2} \cdot (N-n) :: h : h_n .$$

Therefore $h_n = \frac{4\,n\,h\,(N-n)}{N^2}$ (4.)

Similarly, $h_{n+1} = 4\,h\,\frac{(n+1)\,[N-(n+1)]}{N^2}$ (5.)

Substituting these values of h_n and h_{n+1} in equation (3), and reducing, we have for the horizontal component Hn of the maximum stress in any diagonal n of such a truss

$$Hn = \frac{n^2 w'}{2\,(N-1)}\left(\frac{N^2}{4\,h\,(n^2+n)}\right) \quad (6.)$$

Representing the vertical inclination of this diagonal by i, its maximum stress by S_n and the vertical component of this stress by V_n; since the horizontal component is to the vertical component as the panel length (unity) is to the vertical height of the diagonal n, or

$$V_n : \frac{n^2 w'}{2\,(N-1)}\left(\frac{N^2}{4\,h\,(n^2+n)}\right) :: \frac{4\,h\,(n-1)\,[N-(n-1)]}{N^2} : 1$$

we have $V_n = \frac{n\,w'}{2\,(N-1)}\,(N-n+1)$,

and $S_n = \frac{n\,w'}{2\,(N-1)} \times \left(N-(n+1)\right) sec.\ i$ (7.)

The greatest thrust in any vertical web member in a bowstring of this class occurs when the diagonal between it and the head of the load is under its greatest stress, and equals the vertical component of the diagonal transmitting the load from its lower extremity towards the unloaded abutment, because, when the greatest strain occurs at any panel point n, the vertical at n is under tension from the part of the load transmitted to the loaded abutment, and the vertical at the panel point $n+1$, resists as a strut the whole stress then borne by the diagonal $n+1$.

Applying the principles and method employed above in deducing the stress in the diagonal at n, the horizontal component of the stress in the diagonal $n+1$ from the same shearing force $\frac{n^2 w'}{2\,(N-1)}$ is found to be $\frac{n^2 w'}{2\,(N-1)}\left(\frac{N^2}{4\,h\,(n+2)\,(n+1)}\right)$ and its vertical component or the greatest thrust produced by the moving load in the vertical $n+1$ is found by multiplying this expression by the ratio of the vertical height

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Note—Equation (4) affords the readiest means of determining in the process of design the exact heights of the several panel points of the arch from the axis of the lower chord.

of the diagonal $n+1$, to the panel length, and is

$$= \frac{n^2 w}{2(N-1)} \times \frac{N-(n+2)}{n+1} \qquad (8.)$$

As the verticals bear a tensile strain equal to the uniform dead load w per panel, less the weight of the arch, if we represent by w'' the weight of the arch per panel, the total strain in the vertical n is,

$$H = \frac{n^2 w'}{2(N-1)} \left(\frac{N-(n+2)}{n+1} \right) - (w - w'') \qquad (9.)$$

The maximum shears having been determined by equation (3) the graphical method furnishes a more rapid and direct means for determining the resulting stresses in the web members than the analytical formulæ we have deduced.

These shears represent that part of the entire reactions at the unloaded abutment producing the maximum stresses sought in the web members respectively, and may therefore be readily laid off to scale and traced through reciprocal figures to those web members to which they respectively apply.

For example, a strain sheet is required for a wrought-iron bowstring girder of 90 feet span, having a clear roadway of 18 feet and two sidewalks 6 feet wide, and having a rise at the centre of 10 feet.

Let the fixed points of the arch be in the curve of equilibrium and let it be divided into nine panels, and be required to carry a uniform moving load of 80 pounds per square foot of floor surface. The uniform dead load of such a truss, properly designed, will be about 400 pounds per lineal foot, and of its arch about 75 pounds per lineal foot. We, therefore have for the numerical values of our literal factors: $N=9$. $h=1$. $w=4\,000$ lbs. $w'=12\,000$ lbs. and $w''=750$ lbs.

To draw an accurate diagram of the frame, it is first necessary to determine the vertical heights of the panel points $h_1, h_2 \ldots\ldots h_{(N-1)}$. This is readily done by substituting the numerical values for this case in equation (4.) and we have

$$h_1 = \frac{4}{81.} \quad (8) \times 10. = 3.951 \text{ feet.}$$

$$h_2 = \frac{4 \times 2.}{81.} \quad (7) \times 10 = 6.914 \quad \text{“}$$

$$h_3 = \frac{4 \times 3}{81} \quad (6) \times 10 = 8.889 \quad \text{“}$$

Fig 1.

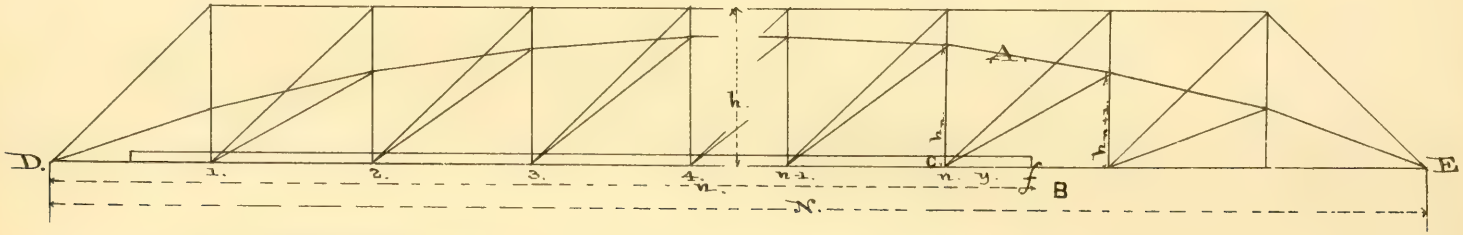


PLATE XXIV
TRANS. AM. SOC. CIV. ENG'RS.
VOL. IX. No. CCX.
SWEETON STRAINS

$$h_4 = \frac{4 \times 4}{81} (5) \times 10 = 9.876 \text{ feet.}$$

$$h_5 = \frac{4 \times 5}{81} (4) \times 10 = 9.876 \quad \text{“}$$

$$h_6 = \frac{4 \times 6}{81} (3) \times 10 = 8.889 \quad \text{“}$$

$$h_7 = \frac{4 \times 7}{81} (2) \times 10 = 6.914 \quad \text{“}$$

$$h_8 = \frac{4 \times 8}{81} (1) \times 10 = 3.951 \quad \text{“}$$

Draw the diagram of the frame *D*, *E*, Fig. 2, Plate XXV., to a convenient scale, with the diagonals required to transmit the panel weight towards the abutment *E*.

Draw to a convenient scale, say 10 000 pounds per inch, the force polygon *A*, *B*, *O*, for the frame fully loaded. That is, draw the vertical line *A B*, representing to the assumed scale 10 000 pounds per inch, the whole dead and moving load borne by the arch $(w + w') \times (N-1)$, and subdivide it into eight equal parts (the number of loaded panel points). Through the extremities and points of subdivision of *A B*, draw lines to the left, parallel to the several members of the arch. These lines will intersect at a common point *O*, and will represent, in direction and intensity, the stresses produced by the full dead and moving loads in the members of the arch to which they are respectively parallel.

The horizontal line *O F*, represents to the assumed scale of weight the stress throughout the lower chord, as well as in the horizontal member of the arch.

Through the vertex *O*, draw an indefinite vertical line, and lay off upon it, on a scale of, say 1 000 pounds per inch, from *O*, downward *O C*, the reaction at *E*, and from *O*, upward *O C′*, the reaction at *D*, produced at those points when the moving load exerts the greatest shearing force at the first panel, that is when n, in the formula

$$\frac{n^2 w'}{(2 N-1)}$$ is unity.

On the principle of the lever, these reactions are in the proportion of 1 to 8. $O C, = \frac{(1)^2 \times 12\,000}{16} = 750$ lbs. and $O C' = 6\,000$ lbs. Through *C*, and *C′*, draw horizontal lines intersecting *O A*, and *O B*, in *G*, and *G′*. *C G*, represents the stress in the first panel of the lower

chord and $O\ G$, the stress in the first panel of the arch from E, due to the reaction $O\ C$. Produce $C\ G$, representing the lower chord, and draw the lines a 7, b 6, c 5, d 4, e 3, f 2, g 1, parallel to the web members, taken in their order from E, and terminating at their lower ends in the lower chord produced, and at the other end in the lines of the polygon representing the panel sections of the arch to which they respectively belong.

These lines represent in direction and in intensity (to the assumed scale of 1 000 pounds per inch) the stress produced in all the web members by the reaction $O\ C$, (750 pounds), and the maximum stress in numbers 9 and 2 due to the moving load. The accuracy of the work is tested by drawing upward from the upper extremity of g the vertical 1, which should intersect its panel member, $D\ A$, at G, and close the polygon of the reactions $O\ C$, and $O\ C'$, due to the whole moving load in the position we have assumed.

It will be seen that the general expression for the maximum shear at any point is composed of the constant factor $\frac{w'}{2\ (N-1)}$ multiplied by the square of the distance or number of the given panel point from the loaded abutment.

We can, therefore, derive the greatest stresses in all the web-members from the reciprocal figure just drawn from the maximum shear when $n = 1$ by multiplying the stresses represented by its several lines to the assumed scale by the squares of the distances of the respective diagonals from D: *i. e.*, multiplying f and 3 by 4; e and 4 by 9; d and 5 by 16; c and 6 by 25., &c. The scale of the members beyond the middle of the arch is so small, however, that it is better to derive them from the reaction of the greatest shear at or near the middle, as for

$n = 5$, where the shear $\frac{n^2\ w'}{2\ (N-1.)} = 750 \times 25 = 18750.$

Lay off this reaction $O\ C''$ on a scale of 5 000 lbs. to an inch, draw $C''\ G''$ parallel to the lower chord, and continue the reciprocal figure to the member of the arch next to the centre, *i. e.*, to c.

The lines C and 6 represent the direction and intensity of the greatest stress on the 5th diagonal and 6th vertical respectively, while the lines a, b and 7 bear the same ratio to the maximum stresses in the members they represent as the maximum shears at the panel points 6 and 7, bear

to that at point No. 5, and their greatest stresses are determined by multiplying b and 7 by $\frac{36}{25}$ and a by $\frac{49}{25}$.

It must be borne in mind that from the thrust in the verticals determined as above, the tension $(w - w')$, produced by the uniform dead load is to be subtracted from each, and that when the moving load passes over the frame in an opposite direction a set of diagonals is required running in the opposite direction to those shown, which will evidently be similarly strained, and that the verticals will then be differently strained, depending upon their distance from E. No. 7 becomes No 2, No. 6 No. 3, and No. 5 becomes No. 4. The greatest of these vertical strains is of course to be provided for.

There remains the case of drawbridges of moderate spans with which the general practitioner has not infrequently to deal, and about which he is often mislead.

As these bridges are usually constructed, the assumption that they consist of three unequal spans, as AD, DD', $D'B$ in Fig. 3, Plate XXVI., is erroneous, since the panel points between D and D' are commonly rigidly fixed to the turntable, and the loads upon them are carried directly by the latter.

So constructed, the cords of the truss between D and D' may be considered horizontal in whatever manner the end spans may be loaded.

Suppose each of the end spans to be divided into N equal panels, and assume the panel length as the linear unit. Suppose the span AD covered with the maximum moving load, and let w' represent the portion borne at each panel.

Take A as the origin of rectangular co-ordinates, and represent vertical and horizontal distances from these axes by y and n respectively.

With the beam thus loaded, the external forces acting upon it between A and D are the several panel weights acting vertically downward, and the reaction R of the abutment A acting in the opposite direction. The panel weights are known, but the reaction R is yet to be ascertained.

Now, by the principle of the lever, the bending moment at any panel point, distant n from A, is the sum of the moments with regard to the panel n of all the weights between A and n, or

$$\{1 + 2 + 3 + \ldots (n-2) + (n-1)\} w' = n(n-1)\frac{w'}{2}$$

But the reaction of the abutment A produces a moment of the opposite kind $= -Rn$. Therefore, the bending moment of this truss at any panel n is $m = n(n-1)\frac{w}{2} - Rn$.

From the differential equation of the elastic curve, we have for any homogeneous beam $m = \frac{d^2y}{dn^2} EI$. Therefore

$$EI\frac{d^2y}{dn^2} = \frac{w'}{2}(n^2 - n) - Rn.$$

Integrating once we have

$$EI\frac{dy}{dn} = \frac{w'}{2}\left(\frac{n^3}{3} - \frac{n^2}{2} - R\frac{n^2}{2} + C\right)$$

Since the beam is horizontal at D, at that point $\frac{dy}{dn} = 0$ and $n = N$. therefore

$$\frac{w'}{2}\left(\frac{N^3}{3} - \frac{N^2}{2} - R\frac{N^2}{2} + C\right) = 0$$

and

$$C = \frac{RN^2}{2} + \frac{w'}{2}\left(\frac{N^2}{2} - \frac{N^3}{3}\right)$$

$$EI\frac{dy}{dn} = \frac{w'}{2}\left(\frac{n^3}{3} - \frac{n^2}{2}\right) - \frac{Rn^2}{2} + \frac{RN^2}{2} + \frac{w}{2}\left(\frac{N^2}{2} - \frac{N^3}{3}\right)$$

Integrating again, we have

$$EIy = \frac{w}{2}\left(\frac{n^4}{12} - \frac{n^3}{6}\right) - \frac{Rn^3}{6} + \frac{RN^2n}{2} + \frac{w}{2}\left(\frac{N^2n}{2} - \frac{Nn^3}{3}\right) + C.$$

For $y = o$; $n = o$. Since there is no deflection at A ; $C = 0$.

For $n = N$ also $y = O$. Since there is no deflection at D.

Therefore

$$\frac{w'}{2}\left(\frac{N^4}{12} - \frac{N^3}{6}\right) - \frac{RN^3}{6} + \frac{RN^3}{2} + \frac{w'}{2}\left(\frac{N^3}{2} - \frac{N^4}{3}\right) = 0.$$

$$\frac{RN^3}{2} - \frac{RN^3}{6} = \frac{w}{2}\left(\frac{N^4}{3} - \frac{N^4}{12} + \frac{N^3}{6} - \frac{N^3}{2}\right)$$

$$\frac{6R}{12} - \frac{2R}{12} = \frac{w}{2}\left(\frac{4N}{12} - \frac{N}{12} + \frac{2}{12} - \frac{6}{12}\right)$$

$$8R = w'(3N - 4).$$

$$R = w'\left(\frac{3N - 4}{8}\right)$$

Substituting this value of R in the equation for the bending moment, we have $M_n = \frac{w'n}{2}(n-1) - \frac{w'n}{8}(3N - 4)$.

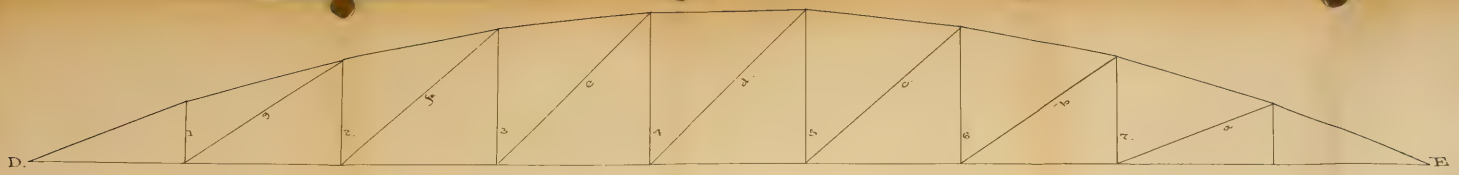
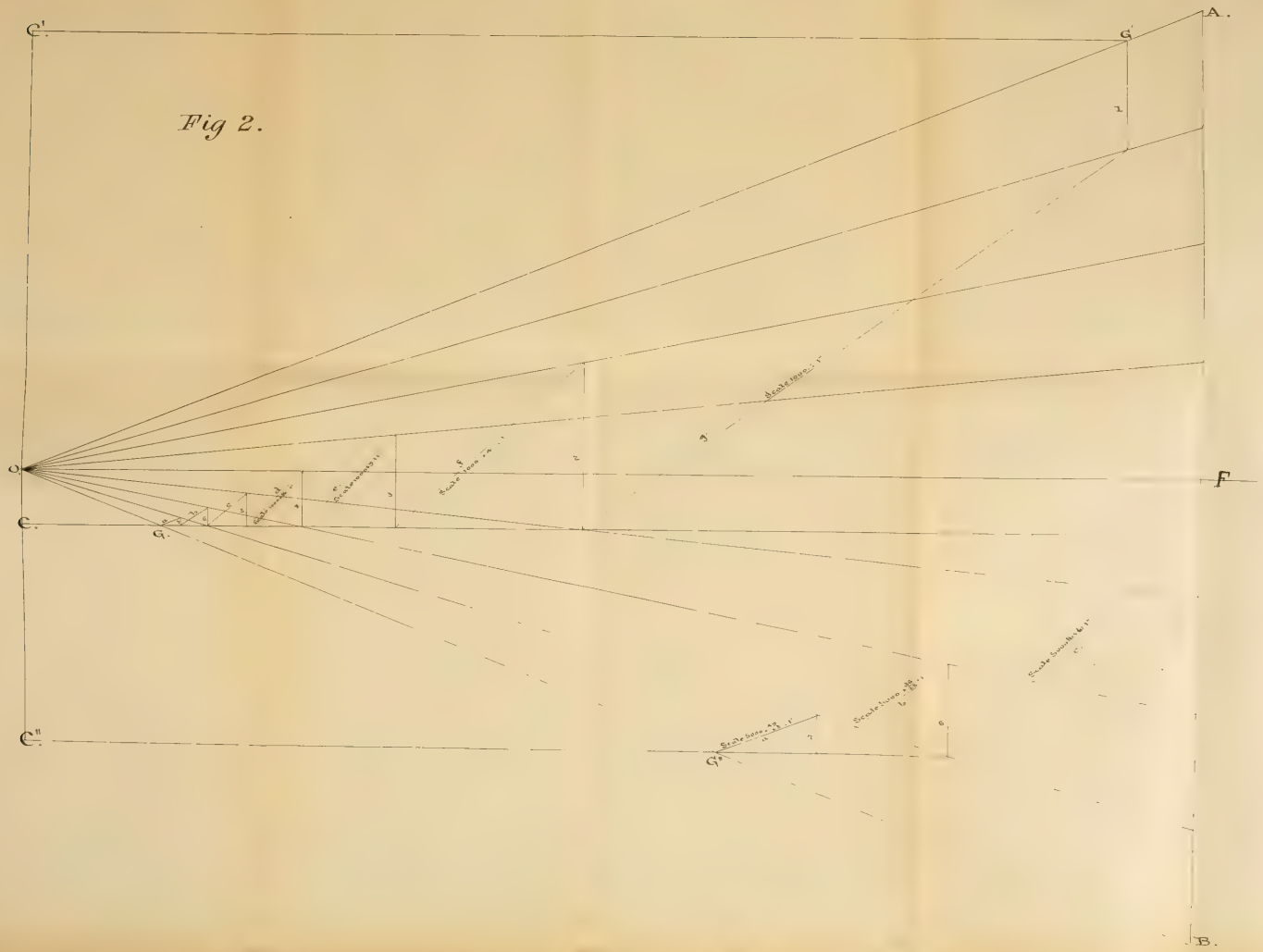


PLATE XXV.
HOWE TRUSS OF TWO SPANS
WITH UNIFORM
SWEEP OF STRAINS

Fig 2.



The bending moment at any panel point n determined by this formula when divided by the height of the truss in terms of the linear unit, gives the strain along the chord opposite the point n.

The web strains in the end spans are obtained by beginning at A or B, with the reaction R, which evidently measures the shearing force at the ends of the truss, and subtracting from this reaction one panel weight successively for the shearing strain at each successive panel point, and disregarding the algebraic sign of the result. These remainders must, of course, be multiplied by the ratio of the length of each brace to its vertical height, to obtain the stresses in the braces themselves. Let T be the strain in any pair of braces intersecting between panel point n and $n+1$. $T=(R-n\,w')\times sec\ i$, in which $i=$ inclination of brace to vertical.

The greatest vertical strains in the braces of the panels over the turntable is the vertical component of the difference of the bending moments at D and D', when one end span is loaded, and the other bears only the dead load, while the maximum strains in the chords between D and D' are the same as at the panel D, or D' with the bridge fully loaded, as determined by the formula.

These formulæ give the maximum strains in any drawbridge of the kind above described due to the moving load, with either or both end spans fully loaded, in which, when the span $A\ D$ is loaded, and $D\ D'$ and $D'\ B$ unloaded, the algebraic sum of the moments to the left of the left edge of the turntable T, is less than the sum of the moments due to the dead weight of the bridge and turntable to the right of T, *i. e.*, if, when thus loaded, the points D' and B do not move from their supports. In the latter case, the chords between D and D' would not remain horizontal, thus destroying the condition upon which we have determined the constants of integration.

The expression $\frac{n^2\ w'}{2\ (N-1)}$ is, of course, inapplicable to determining the maximum shearing strains due to partial loads in simple trusses of this class, for the reason that the point of contrary flexure, and the consequent value of N changes with every change in the position of the load.

These changes are too remotely related to admit of simple analytic expression.

The usual assumption that the panel points are successively fully loaded before any part of the moving load goes forward to the panel in

advance is, however, less inaccurate in this case, than in that of simple trusses supported at both ends, because the point of contrary flexure recedes as the load advances.

On this assumption it is only necessary to determine from the equation of the elastic curve the reactions at A, with the panel points successively loaded.

Thus the reaction at A, for any panel load w' at n, (measured from the fixed end D), is $R_n = w' n^2 \frac{(3N - n.)}{2N^3}$ and with the head of the moving load covering the panel point n, from D the whole load is $n w'$, and the whole reaction from it at A, is the sum of the reactions determined by the above equation for the several panel loads 1 to n, making n equal to each of the natural numbers 1 to n.

The difference between the whole load $n w'$ and the sum of these reactions, is the shear due to the partial load on the brace transmitting it from the point n towards A.

In order that a drawbridge, in which the points of support are in a horizontal plane, may be freely moved to and from its abutment supports, it must be constructed with reversed camber equal to the amount of deflection due to the dead load when the ends are unsupported, so that when open, the dead load makes the lower chord horizontal.

It follows from this condition that the bridge in use is subjected to the combined effect of the strains from the moving load on the assumptions above discussed, and from the dead load supported at the center pier.

The latter strains, as well as the dead load deflection, to be provided for in construction, are determined by the well-known rules for semi-beams.

The algebraic sums of the strains thus determined, and those of the corresponding members due to the moving load computed by the formulæ above discussed, give the total strains on this structure when in use.

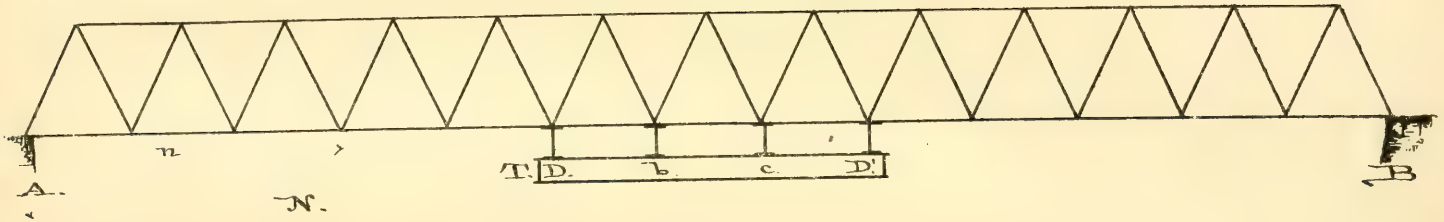


PLATE XXVI
TRANS. AM. SOC. CIV. ENG'RS.
VOL. IX Nº CCX
SWEET ON STRAINS

Fig 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCXI.

(Vol. IX.—November, 1880.)

DISCUSSION

UPON INTER-OCEANIC CANAL PROJECTS.*

ALSO

ADDITIONAL INFORMATION OBTAINED BY RECENT SURVEYS IN NICARAGUA.

By A. G. MENOCAL, Member of the Society.

I have read with much interest the valuable papers contributed by Messrs. W. W. Evans, J. C. Campbell, Max E. Schmidt, Ashbel Welch, and others, published in the Transactions of the Society, and bearing on the pending discussion on Inter-Oceanic Canal communication.

* Inter-Oceanic Canal Projects, No. CLXXXVIII., Vol. VIII., page 311 (November, 1879). Also Discussions, Vol. IX. (January, February, March and April, 1880).

It seems proper for me to reply to certain statements made and objections raised by those gentlemen as to the merits of the proposed canal across Nicaragua, advocated by me in my paper read before the Society November 9, 1879, inasmuch as some of the objections urged are based on a misunderstanding of the facts, and on other points a need of additional information is shown in order to ensure a full appreciation by all.

I will endeavor to be brief in my remarks, confining them to the elucidation of points bearing on the practicability of that route, and its approximate cost, disregarding some questions of detail in dimensions and methods of construction, which, however much they may be modified, within reasonable limits, to meet the views of different parties, will not materially change the estimated cost of the work.

The paper on "A Project for a Canal Across Nicaragua," now being discussed by the Society, was prepared with the object of showing the advantages of that route in comparison with others, and the approximate cost of the work—some of its important dimensions having been fixed by official instructions. It was based on data obtained by a careful examination of the ground, and an actual location of the line, but neither the dimensions adopted, nor the exact location, were intended to be final. On the contrary, it has been repeatedly stated that the details of construction and location, as projected, will have to be modified to meet the views of those under whose direction the canal may be undertaken and to secure all the advantages which an exhaustive survey will certainly suggest. Explorations of the region traversed by the canal line made subsequent to the official survey, have demonstrated beyond question the certainty of an improvement as to location.

I agree with the distinguished engineers above named, and others, that the locks should not be less than 500 feet in length, but on the other hand, they must admit that their lift may also be increased from 10 to 15 or 20 feet, and the number of such structures reduced thereby, so that the additional cost necessary by the first alteration will be compensated in part, at least, by the second and the probable advantage of better location. The same may be said of the proposed dams across the river San Juan. Their number can be reduced to two, and the new fall of 20 and 34 feet resulting from the change, cannot alarm any engineer when sure of solid homogeneous foundations and good materials of construction. Such a change will not only reduce the cost of the work considerably, but, what is greatly desirable, increase the depth and width

of the river channel, and so facilitate navigation. When these and other modifications, and the necessary changes in the location are introduced in the original plans and estimates, it will be seen that the saving effected thereby will equal or exceed the cost of certain alterations that may be found necessary. I am now engaged in making a verification of certain portions of the first survey, by which a reduction of the estimate of no less than $2,000 000 is confidently expected. The discussion of the detailed dimensions of the several parts of the work proposed seem to me premature, and a waste of time. We are now considering the problem in its general conditions and such essential features as may effect its practicability and probable cost, disregarding those questions which can be settled at any time without affecting any conclusions we may now arrive at.

I will now try to meet the arguments in the order in which they have been presented, and will go out of the Nicaragua route only so far as may be required to sustain certain statements contained in my paper, and bearing on other projects.

Mr. W. W. Evans opens the discussion by several axioms, the accuracy of which cannot be doubted. He might have added, however, that a strait of great width and depth, a Bosphorus or Gibraltar, but free from currents or obstructions of any kind would be the most desirable water communication across the Isthmus. Unfortunately for us, such a strait does not exist, and the question is, can it be artificially made with the means at our command.

I regret very much to disagree with so well known and distinguished an engineer as Mr. Evans, on points touching the problem under consideration, and hope that by throwing more light into the discussion, we may yet arrive at an understanding and agreement as to the essential points of difference between us. Such a result would be extremely gratifying to me.

Mr. Evans objects to the proposed dams across the river San Juan on the sole ground of the danger impending from the failure of such works. The same fears may be entertained as to the stability of retaining walls, bridges, tunnels, &c.; they have also yielded, and will continue to yield, when defectively constructed, or subjected to strains greater than they can resist, but accidents to such constructions have not, as yet, been considered a sufficient argument to prove the necessity of abandoning those systems for overcoming engineering difficulties, nor does there

seem to be any good reason to doubt their stability or utility when properly constructed. The dams proposed across the river San Juan have but a moderate fall, varying from 10 to 23 feet; their sites have been selected where firm foundations and abutments can be obtained, and with those conditions secured, good materials and fair engineering, no fear need be entertained as to their safety. I need not cite examples of existing dams, more than a hundred feet in height, that have been standing for generations, or even centuries, and compared to which the proposed San Juan dams will be lilliputian.

Objections are raised to the location of the canal on the side of a valley and misgivings are felt as to the stability of embankments where heavy rains occur. An examination of the map will readily show that the valley on the north side of the river San Juan, between the San Carlos and San Juanillo, has a very limited water shed drained by but few small streams, and the ground being high, a canal built along that valley, can be effectively drained into the river. From the head of the San Juanillo to Greytown, with the latter river on one side, and the San Juan on the other, a perfect system of drainage can be easily secured for the canal. As to the melting of the embankments during the rain, the objection may to some extent prove to be real in the valley of the San Juan, at certain periods when the rain fall is greatest; but the objection, when applied to the region between the lake and the Pacific, is entirely groundless. There no rain falls for five months in the year, and the total precipitation does not exceed 55 inches. With the rapid growing vegetation found along the whole line of the canal, and the firm soil composed as it is of clay and gravely clay, this danger will be found to be less than anticipated.

With all due respect for Mr. Evans' opinion as to the insufficiency of the prices adopted, I would prefer to leave them as originally recommended. Many engineers and contractors of large experience have considered them quite ample, and some have even gone so far as to express their willingness to undertake the works at the prices estimated.

Omissions are likely to occur in the first estimate of a work of this kind, and I admit that some may have been made in the present case; but they are of comparatively little importance, and will not alter materially the figures given. They are, certainly, of no consequence, when compared to those made by Mr. Evans in his estimate for the San Blas route, where no provisions are made for shoring and inside lining of the

tunnel, for shafts for the same, tide locks or basins, or for dredging and other excavations under water in the bays of San Blas and Panama.

Mr. Evans says that the supposition that the rock on the San Blas route is too soft to sustain itself, is "moonshine," and adds that, "we know from mines and cuttings over all that country, and from surface rock that crops out everywhere, just what we may expect." He says that, "we know we have rock in fixed quantities, and, by estimating it as *granite*, we know that the estimate cannot be far wrong." As to the first proposition, I have to confess that such a discovery has escaped my observations during repeated and prolonged visits to the Isthmus; besides it is well known there are no mines or cuttings in the region of San Blas, except the deep gulleys on the mountain sides, excavated by the scouring action of the waters, and to show the little reliance to be placed on the surface indications, I will state that M. de Lesseps' engineers made a boring near San Pablo, on the line of the Panama Railroad, close to a very large outcropping of rock, and reached a depth of 60 feet through clay and sand without striking the rock. Similar results have been obtained at other places. On the selected site for the proposed dam across the Chagres river, where rock is also seen on the surface, three borings had been commenced when I crossed the Isthmus in the latter part of March last, and although a depth of from 18 to 24 feet had already been reached, no traces of rock had been met with.

Mr. Evans gives us a very interesting description of his journey through the Suez Canal, and, based on his experience of delays and accidents met with in that single trip, and the time required to haul the steamship *Britannic* into her berth at New York, estimates the probable rate of speed of steamers going through the Nicaragua Canal at 2½ miles an hour and 1½ hours to pass each lock. On the San Blas route he estimates, however, 10 hours to go through 30 miles of canal, 8 of which are in tunnel, with no allowance for passing the tide locks or basins, or for time lost in waiting for a favorable state of the tide for going into or leaving the canal in the Bay of Panama.

It seems strange that an engineer, in discussing the time of transit through a canal on the Nicaragua route, should not take the pains to separate the 181½ miles of what he calls "canal" into its component parts, in doing which he would find canalization 62 miles, slack water navigation, admitting nearly ocean speed 63 miles, and lake navigation, admitting ocean speed, 56½ miles. With this explanation "old canal

men and sailors accustomed to handling these huge vessels" will *not* look with a smile on the estimate of 38½ hours to pass through what is called a canal 181½ miles long, having a lockage of 108 feet. It is interesting to note that some engineers of eminence do not agree with Mr. Evans in his estimate of time required for navigation of canals and passage of locks by large ships. General Gillmore's recent report on the Florida Canal (Senate Ex. Doc. No. 154, 46th Congress, 2d Session) has just been printed. The following are data taken from that report: Length of canal, 122 miles; river and approaches, 47 miles; height of summit, 108 feet; number of locks, 15; estimated speed for ship of 3 000 tons in canal, 5 miles per hour; in river, 9, and in Cumberland Sound, 12½ miles; total time of transit, including 15 lockages, 40 hours; excavation, 108 million yards; cost, $50 000 000.

Mr. Evans objects to the prism recommended for the Nicaragua Canal as insufficient, and in the same paper proposes dimensions for the San Blas route, the water section of which is not larger than the one he criticises.

The River San Juan being the outlet of Lake Nicaragua, the water-shed of the latter is, undoubtedly, a portion of that of the river; but with the two lakes, Managua and Nicaragua, with an aggregate area of 2 700 square miles, acting as equalizing reservoirs, a five-inch rain-fall cannot produce any considerable rise in the River San Juan, of which the first 30 miles have only a fall of 24 inches, and may be properly considered as an extension of the lake With these conditions it is difficult to conceive how a five inch rain in the lake region can develop foot-pounds of energy or force for doing mischief measured by 4 000 millions of tons falling 107 feet, as apprehended by Mr. Evans. It may be proper to state here, and in this connection, that the Government Custom House, situated near the upper part of Castillo Rapids, at an elevation of not more than five feet above the mean level of the river, has been standing for many years, and there is no record of its building site ever having been flooded.

Referring to the doubts which seem to be entertained as to the character and amount of excavation and dredging required in the bottom of the lake and River San Juan, near San Carlos, I will state that, sounding through the mud to a depth of 20 feet or more, both in the lake and river, and extending to some distance from San Carlos, failed to detect any rock. On the west side the excavation, needed to obtain 30 feet depth at the entrance to the canal, will have to be made in gravel and

fissured rock, and will extend some 1 200 feet from the shore of the lake. An examination of the profile will show that the amount of excavation required is not great nor so difficult to compute as suggested by Mr. Evans.

Reference has also been made to high waves and strong winds on the east side of the lake. This statement is quite true for the Chontalis Coast during a brief portion of the year, when the winds blow from the south-west. But in the vicinity of San Carlos, where dredging is proposed, the lake is well protected by the islands to the west, the winds are light, and the waves are never more than 1½ or 2 feet high.

Mr. Evans does not give credence to the reports as to the calms of the Bay of Panama, and probably believes what has been said on that subject also to be "moonshine." Navy men, however, have a different opinion on that point, and are never anxious to be caught in that trap with their sailing vessels.

Mr. John C. Campbell is of the opinion that the surveys made to the present time are insufficient to establish the best location for a ship canal across the Isthmus. That is the first point in his paper in which we disagree. I believe that the several points presenting favorable indications for the construction of a water way have been sufficiently examined to enable us to determine the relative merits of the several routes. The cry for more surveys generally comes from parties not well informed as to what has been accomplished.

It is rather unfortunate that while Mr. Campbell declares as incorrect my statement respecting the yearly rain-fall at Aspinwall and different places in Nicaragua, he is unable to give any figures to sustain his assertion, but confines himself to a repetition of what General Totten has said on that point, and on reports he had heard while at Aspinwall as to the rain-fall at Greytown.

He says that the elevation of 123.75 feet above mean tide, fixed for the summit level of the Panama Lock Canal by the aqueduct at Matachin is unnecessary, and that a good crossing can be had below Gorgona, and another near Barbacoas. This assertion I will regard as untenable unless Mr. Campbell can show by his plans and figures by what methods and at what cost he proposes to overcome the difficulties arising in clearing the nest of high precipitous hills on the north of the Chagres River at and below Matachin, and, what seems to be still more difficult, to retain the surface of the water in the canal at the required elevation across the

low and extensive valleys between the ranges of hills near Gorgona and Barbacoas. At the latter place the railroad approaches the bridge on an embankment of some elevation, and it would be important to know the length and height he would propose for the necessary aqueduct to cross the river at this point.

Mr. Campbell says that in the design for the aqueduct at Matachin I made no allowance for the water way of the arches, increasing thereby the height of the summit level, a remark which I take as implying that such margin was, in his opinion, unnecessary. No engineer familiar with the peculiarities of the River Chagres and its power for doing damage could consider me either too extravagant or timid in that design. Should I have to make another for the same work, and profiting by the teaching of last November's flood, I would feel inclined to enlarge rather than diminish the water way.

I cannot claim that the line between Aspinwall and Panama surveyed by the United States Expedition is the best route for a lock canal connecting those two points. On the contrary, I believe the location of the canal and the feeder routes are capable of important improvement by a more detailed survey. They are, however, lines of actual location, which cannot be said of any other canal route spoken of or estimated upon, across the Isthmus of Panama. Should Mr. Campbell take the trouble to go over the ground upon which the canal and feeder lines have been located, he would understand why seven tunnels and two syphons were found necessary for the feeder, and also the reasons for the estimate of $18 331 343 for culverts and drains on the canal, which he regards as unjustifiable. In crossing low and extensive valleys running between elevated ranges of hills, such as those in the vicinity of Gorgona and Barbacoas, he would find that the amount estimated under that head is not excessive. He would also find that, in that survey the imagination was not so heavily taxed as he presumes, and that although the survey was completed by two field parties in a little less than three months—not two months, as he incorrectly states—the plans presented deserve all the credit that has been claimed for them respecting the amount of information they give as to topography of the line surveyed.

Referring to my statement that there is on the Panama route a total lack of building materials for the construction of the works recommended, he says that, "this is a discovery that no other man has

made," and adds, "that the Panama Railroad has a number of bridges, all with stone piers and abutments, and it is a new idea that walls cannot be built with stone suitable for bridge works." I am indebted to Mr. Campbell for the compliment; but, really, I am not entitled to any credit for what he supposes a new idea. In making my statement I have only followed an old rule established by many authorities and confirmed by practice, that soft and porous conglomerate, such as can be obtained at Buhio Soldado, the best stone quarry between Aspinwall and Panama, is not a suitable material for the construction of canal locks, aqueducts or sea walls exposed to heavy seas. That material has been made to answer in the construction of piers and abutments for bridges, by employing it in heavy masses; but a close observation of those works and of the storehouses at Aspinwall would have shown Mr. Campbell that the stone he recommends is rapidly crumbling to the ground.

With all due respect for the professional experience of Col. Totten, at Panama and elsewhere, I am not disposed to accept as conclusive his estimated cost of a canal with locks at Panama, as given by Mr. Campbell, until I know that his figures are based on data obtained by the location of a line for that purpose, If such a survey has ever been made, I am not aware of it, and it would be extremely interesting to see the plans and profiles, now that we are seeking for information bearing on that important question.

It may be of interest to state here some information recently obtained as to the flow of the river Chagres, the only available source of supply for a canal with locks at Panama. In crossing the Isthmus in the month of March of the present year the volume of that river was so much reduced by the continuous dry weather of the preceding three months, that its channel at some places was not more than 50 feet wide and nine inches deep, with a flow of not more than 200 cubic feet per second. One of the engineers of M. de Lesseps' suite, engaged in the canal survey, told me that the river could be waded at many places with the water below his ankles. How much more its volume was contracted before the rainy season commenced I could not state, but it is evident the supply of water from that river cannot be relied upon for the supply of a lock canal at all times of the year.

Mr. Ashbel Welch's interesting and valuable paper is full of suggestions that deserve the greatest consideration. Many of them, however,

are alluded to in my remarks as to the details of the different parts of the work proposed or have been already referred to in this paper. I will, therefore, confine myself to reply to such objections or propositions only, as I believe to be based on a misapprehension of the natural conditions affecting the solution of the problem.

Mr. Welch objects to the depth of 26 feet, and width of 72 feet at the bottom, proposed for the canal, as insufficient. Vessels drawing more than 24 feet could not navigate it, and those of 42 feet beam could not pass each other. He suggests 28 feet as the proper depth for the canal. This latter depth would, certainly, be preferable, and will probably be ultimately adopted, should the work be undertaken ; but we have before us the experience of the Suez Canal, which with the same dimensions as have been proposed for the one under discussion, has met quite satisfactorily all the demands of navigation. It is not intended that two vessels of the dimensions named by Mr. Welch shall pass at all points. For a traffic of six millions tons a year, it is not likely that more than nine vessels will, on an average, pass through the canal every day ; and with the lake and river comprising about two-thirds of the whole distance across, and with lake Silico seven miles from Greytown, it may well be assumed that the traffic could be so regulated that vessels in transit will not meet each other on any of the narrow reaches. Should the requirements of the traffic demand it, two or more turnouts at convenient places would meet the difficulty.

The slopes of 1½ to 1 for excavations in earth have been accepted as sufficient for the reason that the roots of rapid growing and dense vegetation, reaching to several feet below the water line, in the region of the canal have proved an excellent protection for the banks of the river and will do the same for the canal banks and slopes.

Mr. Welch says that "the dams proposed are sufficient to pass the maximum flow of water from the lake, but not to pass in addition the water that accumulates in the basin of the San Juan, between the lake and the mouth of the San Carlos;" and adds that, "taking thewater-shed of that portion of the river at 1 500 square miles, a rain-fall of one foot may produce a discharge of 400 000 cubic feet per second and a rise of 18 feet over the crest of a dam 1 000 feet long."

Such a rise has never been seen on the river San Juan, not even below its junction with the San Carlos and Serapiqui ; nor is it likely to occur under the conditions named. More than 37 miles of the 63 miles

of the river intended to be utilized for the canal, will be for all practical purposes on a level with the lake, and a rise in that basin would produce a division of the waters, a great portion flowing towards the lake. Moreover, the large channel of the San Juan, greatly increased by a considerable rise would form a reservoir large enough to store the greater portion of the rain-fall named, so that the flow, even under those conditions, cannot attain the magnitude supposed by Mr. Welch. I do not anticipate a rise of more than 6 feet over the crest of the dams, and the height of 10 feet fixed for the abutment wall may be regarded as sufficient.

Mr. Welch proposes to raise the surface of the lake 12 or 15 feet more than I have recommended. However desirable this modification of the plan may be, it could not be carried out without flooding many hundreds of square miles of the most valuable lands of the country, and destroying whole towns and villages situated near the lake, so that the damages done, would not in my judgment, be justified by the advantages gained. The additional rise of from three to four feet proposed by me can be adopted without hesitation, and about two-thirds of the excavation in the lake and river saved thereby.

The following additional information obtained by recent surveys in Nicaragua may be of interest to those members of the Society who have studied the problem of inter-oceanic communication across the American Isthmus.

It has been stated in the official reports of the surveys made by the United States Expeditions of 1872–3, and by other authorities, that two lines had been located for the canal between Lake Nicaragua and the Pacific—one extending from the mouth of the river Lajas, on the lake, to the Port of Brito; the other from the mouth of the river Del Medio to the same terminal point on the Pacific.

The portion where there is a difference in location is between the lake and the first lock on the Pacific Slope, or, in other words, in that portion of the canal where the level of the lake is to be extended westerly. From lock No. 1 they have a location in common. The deepest cuttings required to reach the proposed level of the canal are: For the Lajas line, 43¾ feet; for the river Del Medio route, 134 feet; the length of the respective lines being $17\frac{27}{100}$ miles for the former, and $16\frac{33}{100}$ miles for the latter. The estimated cost of the Del Medio route exceeded that of the Lajas by several millions, but after mature considerations, and by reason

of better natural surface drainage, so essential to the stability of a work of this kind built in a country subject to large rain-fall, the river Del Medio route was favored. On this line no water course of considerable size would be taken into the canal, and as its water shed is quite small, no fears were entertained of damages from freshets. On the Lajas route the conditions were dissimilar, the river Grande, a mount ain stream of extensive and rapidly inclined water shed and precipitous channel, approaches the canal from the southwest, and turning to the northwest, passes, with many sinuosities, through a narrow valley of a width but little greater than required for the canal. The channel of the river has an average width of 60 feet, and a depth of from 15 to 20 feet, and in its tortuous course alternately approaches the basis of spurs of a variable elevation, projecting from the main hills on either side. Col. Childs, who, in his plans for a canal by this route, had proposed to receive this stream into the canal by a waste weir, estimated its maximum flow, calculated from the highest water marks on the banks and its mean sectional area and descent, at 5 670 cubic feet per second. I have been able to obtain, as a result of my own observations, and from information furnished by old residents in the vicinity, what may be regarded reliable data as to highest water marks, which, with the mean descent of the river for several miles, and its average water prism, shows that the maximum flow may be as great as 10 000 cubic feet per second. It is quite certain that this stream seldom rises to the height assumed, and since its water shed is very abrupt it remains but a few hours at the high water marks pointed out to me. But so large a volume of water could not be received into the canal, at a time when least needed as a feeder, even under the most favorable conditions of flow, without danger to navigation and to the stability of the works. This was the greatest objection to this route, and to obviate it, the preference was given, not without reluctance, to the river Del Medio route.

Partial examinations of this region, conducted during visits to Nicaragua, subsequent to the official surveys, had greatly added to my former knowledge of the territory traversed by the canal. I was thus aware that important changes in the original location could be introduced, but there was required an instrumental examination in order to determine the measure of the benefits to be derived therefrom. My last survey on this portion of the canal route, made under orders from the Government, was for the special purpose of ascertaining the practicability of

turning the river Grande into the lake, thereby leaving the narrow valley now occupied by its channel across the divide, free for the construction of the canal. With this purpose in view, the survey was begun at a well-known station and bench mark of the survey of 1872, and carried along the bed of the river Grande to its confluence with the river Cascabel, its main tributary, Plate XXVII. Special care was taken in noting all desirable sites for dams. Ascending the stream, the first was found at "El Carmen," a point 3 000 feet, by the river, from the line of the canal. At this point the bed of the stream is $108\frac{4}{10}\frac{3}{0}$ feet, and the highest water mark $124\frac{3}{10}\frac{8}{0}$ feet above mean sea level. From the site of the proposed dam a transit and level line was run in a southwesterly direction, crossing the divide between the Grande and Lajas with an elevation of $178\frac{3}{10}\frac{8}{0}$ feet (see profile of artificial channel, Plate XXVIII). The line then fell into the brook "Comalcagun," an affluent of the river Juan Davila, the main branch of the Lajas. Following the brook across the extensive valley of Ivcotes, the Juan Davila was reached at a distance of $3\frac{8}{10}\frac{8}{0}$ miles from the bank of the river Grande, and at an elevation of $128\frac{2}{10}\frac{7}{0}$ feet.

To turn the river Grande into the Juan Davila, and through the latter and the Lajas, into the lake, a dam $39\frac{6}{10}\frac{7}{0}$ feet high will be required, this height being the aggregate of the difference of level between the river Grande and Juan Davila, and the necessary fall of the artificial channel, as follows :

Elevation of bottom of river Grande.....	110.87	
" high water mark of river Grande....	127.37	
		16.50 ft.
" water in Juan Davila.....	128.27	0.90 "
" high water in Juan Davila.....	140.73	
		12.46 "
Fall of artificial channel at 2.53 feet per mile.....		9.81 "
Height of dam above bottom of river Grande =		39.67 ft.

The required height of the dam being established, it was observed that in times of high floods the water in the artificial channel would inundate to the depth of two or three feet the valley of Jobito, and possibly escape into the river through some pass between the hills. Another site for a dam was, in consequence, fixed some distance above the first, and the line for the artificial channel was relocated over higher ground.

The profile, Plate XXVIII., represents the corrected line, and elevation of dam resulting therefrom. The proposed channel is 75 feet wide at the bottom, 15 feet deep, has slopes of 1 to 1, and 2 to 1 respectively, for rock and earth excavation, and with the proposed fall of 2.53 feet per mile will have a discharging capacity of 10 273 cubic feet per second, or more than the largest estimated flood of the river Grande. The elevation of the water of the Juan Davila at its confluence with the artificial channel is $128\frac{27}{100}$ feet in the dry season, and $140\frac{73}{100}$ feet at high floods, or 18 feet and 30 feet respectively above high lake; and the distance from the river being about six miles, there will be a fall of from three to six feet per mile, which in the broad channels of the Juan Davila and Lajas, need occasion no apprehension of the waters rising upwards of nine feet above highest recorded floods, backing into the Grande and flowing over the dam.

Having established the practicability of diverting the river Grande, I directed my attention to a careful examination of the narrow valley occupied by the river, having in view a relocation of the canal route so as to utilize the channel of the river, wherever practicable, avoid the hills on both sides, and enlarge the radii of the curves as much as the topography of the country would permit. The relocation made, as shown by the map and profile, Plates XXVII. and XXVIII., is more favorable than was expected, and the estimated cost of the work, as given below, will show the large amount saved by the substitution of this route for that of the river Del Medio, while the drainage of the latter is, in no respects, better than that of the former.

In computing the amount of excavation required by the new profile, a uniform width of 72 feet at the bottom, and a depth of 26 feet, with slopes as before, have been assumed throughout. That being the maximum width adopted for the river Del Medio route, a fair comparison of the relative cost of the two lines can be made, leaving for another place the consideration of the necessary increase of cost resulting from a modification of the dimensions originally recommended; changes that would affect one as well as the other route.

The following is the amount of excavation and embankment required by both routes, with their estimated cost :

PLATE XXVII
TRANS AM SOC CIV ENG'RS
VOL IX Nº CCXI
MENOCAL
ON INTER-OCEANIC CANAL PROJECTS

U.S. NICARAGUA SURVEY, 1872
WESTERN DIVISION

FROM BRITO TO MOUTH OF RIO LAJAS,

ALSO SHOWING RIO del MEDIO LINE
AND THE CHANNEL FOR TAPPING THE RIO GRANDE.

Compiled from Surveys 1872 & 1873
and additional Survey of 1880 by A.G. Menocal U.S.N.

Length of Canal 17.27 St. Miles.

	Cubic Yards.		Price.	Estimated Cost.	
	Del Medio.	Lajas.		Del Medio.	Lajas.
Excavation in rock	2 915 812	1 359 582	$1 50	$4 373 718	$2 039 373
Excavation in rock above prism	7 907 812	2 719 165	1 25	9 884 765	3 398 956
Excavation in earth	6 583 788	7 224 282	0 35	2 304 326	2 528 498
Embankment	2 247 565	781 051	0 10	224 757	78 105
Total				$16 787 566	$8 044 932
				8 044 932	
Difference				$8 742 634	

For a fair comparison of the two routes, the cost of the dam and artificial channels should be added to the estimated cost of the Lajas line.

Estimated cost of cutting the artificial channel:

1 592 434 cubic yards excavation in earth, at 35c	$557 352
403 649 cubic yards excavation in rock, at $1.25	504 561
Total	$1 061 913
Estimated cost of dam across river Grande	140 000
Artificial channel at the mouth of river Lajas	488 000
Total	$1 689 913

Deducting this amount from the difference in the estimated cost above given, we have the total saving (under the same conditions and price for quantity of work) of $7 052 721.

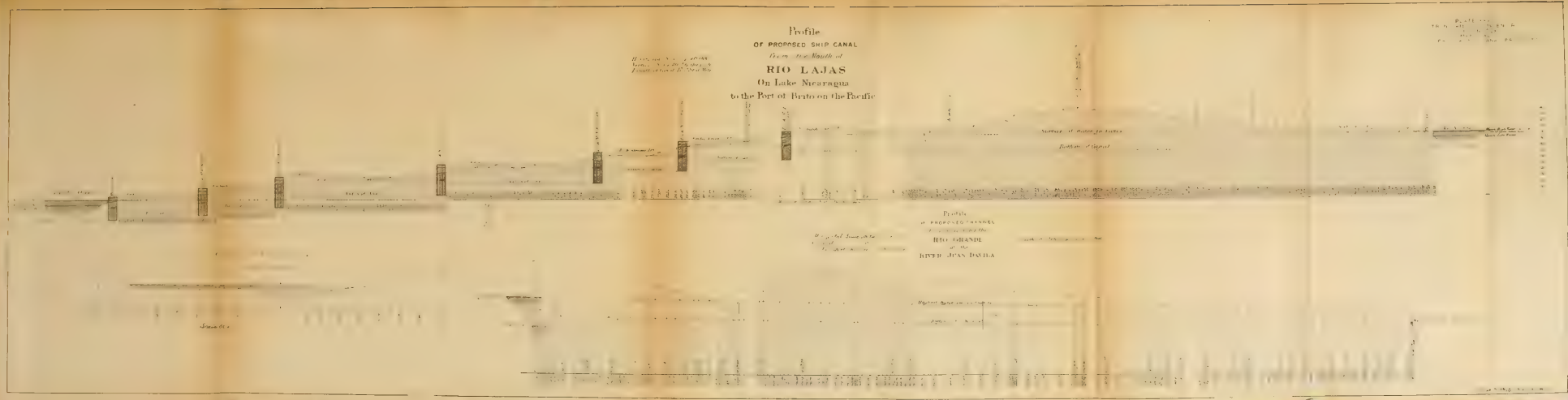
It will be observed from an examination of the profile submitted, that the leve of the lake has been assumed at $110\frac{6}{10}\frac{3}{0}$ feet above mean tide, the height it attained at the end of the rainy season of 1878, and that the different reaches of the canal below the first lock have been located almost altogether in excavation, which is not the case on the Del Medio route; so that there has been an increase of excavation and a proportioned decrease of embankment in that portion of the line. The figures in the estimate for the Del Medio route have not, however, been changed.

The height assumed for the summit level, $110\frac{6}{10}\frac{3}{0}$ feet, an increase of three feet to that proposed in the original plans, will bring a decrease of

2 380 980 cubic yards of dredging and blasting under water in the lake and river, which, at the prices adopted, amount to $1 356 900.

In the original plan for slack-water navigation in the river San Juan, it was recommended to build four dams, varying in height from 21 to 32 feet above the bottom of the river, and three short canals with locks to connect the different reaches. An excellent site has been found above the river San Carlos, where a single dam of over 2 000 feet in length and 59 feet in height above the bottom of the river, or 49 feet above the surface of the water, will secure an uninterrupted river navigation a distance of more than 63 miles, or a continuous summit level of more than 130 miles between the first locks on either side. The advantages to be gained by this modification cannot be over estimated, not only on account of the reduced cost, but, what is of very great importance, the large increase in depth and width of channel gained in the whole river navigation. The estimated cost of the four dams proposed in the original plans amounts, in the aggregate, to $1 543 526, and that of the short canals to $1 056 922. Supposing the single dam now recommended to cost as much as the other four, there will yet result a saving of over $1 000 000, the cost of the small canals, and $283 000 the cost of the designed diversion of the river San Carlos, now uncalled for.

When the canal line extending from below the river San Carlos to Greytown was located by the surveying expedition of 1873, but little information concerning the topography of the country beyond the valley in close proximity to the river could be obtained. The rainy season was near at hand, and the *personnel* of the expedition was too limited to admit of detaching from the main work of location for the purpose of exploring an entirely new region, in which the chances of finding a more favorable location than was known to exist along the left bank of the river were very remote. More than one attempt was made in that direction, but without definite results. The line was, in consequence, carefully surveyed as delineated in the plans accompanying the official reports, and whatever is there shown, may be relied upon as a truthful representation of the natural conditions, and what was proposed has been regarded as entirely feasible. Some time after the completion of that work, I had occasion to make a complete survey of the river San Juanillo and lower valley of the San Juan, a region scarcely known even by the natives of the country. The information then obtained, sustained by subsequent explorations, indicated the possibility of finding a far more advantageous


Profile
OF PROPOSED SHIP CANAL
From the Mouth of
RIO LAJAS
On Lake Nicaragua
to the Port of Brito on the Pacific
Profile
of PROPOSED CANNAL
RIO GRANDE
RIVER JUAN DAVILA

location for the canal route, so that diverging the line from the vicinity of the river San Juan at a point seven miles below the mouth of the San Carlos, it would reach the harbor of Greytown by an almost straight line. It was expected by the new location to save several miles of canal, and, what is of greater importance, to dispense with the sharp curves made necessary by the abrupt bends of the river and high spurs projecting from the main hills in the interior to the waters edge, and relieve the canal from the drainage of many square miles of water shed that had to be provided for by the original plan.

I regret very much my inability to present now the results of an instrumental examination, with plans and profiles showing a line of actual location on which to base an estimate of cost, I am able to affirm, however, that the proposed change is entirely practicable. A personal inspection of that region, conducted with the assistance of a pocket compass and aneroid, shows that the canal line can be taken from the left bank of the river San Juan, at a point six miles below the San Carlos dam, and located over very favorable ground, in an almost straight line to Greytown. The distance saved will be about 7.4 miles, as compared with the first location. Deducting from this distance the needed increase in length of canal on account of change of site for dam, we have the total, as the distance saved, six miles.

I can safely state that the new location will be found more favorable than the first; but assuming the cost of excavation and embankment, per mile, to be the same for both lines, we have an economy in construction of $1 917 336.

The total length of the route from the Atlantic to the Pacific with the changes of location herein referred to is:

From the lake to the Pacific	17.27	miles.
Lake navigation	56.50	"
River navigation	63.90	"
Canal from river San Juan to Greytown	35.90	
Total	173.57	miles.

Of which but $53\frac{5}{10}$ miles is actual canal.

The aggregate saving by the several changes proposed, is as follows :

By Lajas route	$7 052 721
Dredging and blasting in lake and river	1 356 900
Short canal in river San Juan	1 056 922
Six miles of canal between the river and Greytown	1 917 336
Total	$11 383 879
Which, deducted from the orginal estimate	52 577 719
We have, estimated cost of the work, on the same basis	$41 193 839

I present these figures in the hope that if interest in the subject continues, such discussion as would add to our information may result.

ERRATA.

Transactions Vol. IX., page 327, August, 1880.

Formula at bottom of page should read—

$$x\,y = -\,bl \text{ (a constant)} \quad (11)$$

Transactions Vol. IX., page 352, September, 1880.

Seventh line, for *best* absorbent, read least absorbent.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCXII.

(Vol. IX.—December, 1880.)

THE STRENGTH OF WROUGHT IRON COLUMNS.

By G. BOUSCAREN, Member A. S. C. E.

READ SEPTEMBER 1ST, 1880.

The construction of the bridge over the Ohio River for the crossing of the Cincinnati Southern Railway in 1875, and the subsequent letting during the same year of the contracts for nineteen other iron bridges and viaducts for the same road, including the important structures over the Kentucky and Cumberland Rivers, were the occasion of my first experiments on the strength of wrought iron columns.

Gordon's and Rankine's empirical formulæ, deduced from Hodgkinson's experiments on solid bars of small sizes, and used almost exclusively by American engineers for the determination of the sectional areas of compression members, are as follows:

$$\text{Gordon's } \frac{P}{S} = \frac{f}{1+\frac{a\,l^2}{h^2}}$$

$$\text{Rankine's } \frac{P}{S} = \frac{f}{1+\frac{a'\,l^2}{r^2}}$$

P=Ultimate load in lbs., producing the crushing or bending of column.

S=Sectional area of column, in square inches.

f=Constant, supposed to be equal to the ultimate resistance per square inch of a short column whose length is equal to its diameter.

a=Constant
- For columns with flat bearings at ends $= \frac{1}{3000}$
- For columns with flat bearing at one end and rounded at the other..... $= \frac{2}{3000}$
- For columns rounded at both ends..... $= \frac{4}{3000}$

a'=Constant
- For columns with flat bearings at both ends $= \frac{1}{36000}$
- For columns with flat bearing at one end and rounded at the other..... $= \frac{2}{36000}$
- For columns rounded at both ends..... $= \frac{4}{36000}$

l=Length of column in inches.

h=Diameter of column in the direction of its greatest deflection.

r=Radius of gyration of cross section of column in the direction of its greatest deflection.

Gordon's formula, the most popular of the two, seemed to be accepted without sufficient experimental evidence of its correctness, as applied to a great variety of shapes, almost every individual bridge builder having his preferred value for Constant "f."

In preparing the specifications for the above named structures, I prescribed Gordon's formula, with the proviso that experiments would have to be made to determine the value of the constant "f" to be used for each kind of iron and shape of column proposed by the contractors.

Thirty-four experiments were made during the year 1875 in accordance with these specifications, whereby columns and struts of various shapes and of the full size to be used in the structures, were crippled under pressure in a hydraulic press.

Tables numbers 1, 2, 3, 4, and 5, give the sizes and other characteristics of each of the columns tested, the results of each test and the corresponding calculated values of the constants for Gordon's and Rankine's formulæ.

In 1877, Experiments Nos. 35 and 36, Table No. 5, were made on the occasion of the construction of the bridge across the Tennessee River for the Cincinnati Southern Railway, to verify the assumption made in the calculations, that an open column composed of two channel bars latticed should be calculated by Rankine's formula with the same constant as for a closed column composed of channel bars and plates of the same kind of iron.

In 1878 and 1879, similar latticed posts having been adopted in the designs of the thirty-four iron structures contracted for by the Keystone Bridge Company, for the completion of the road, experiments No. 37 to 43, inclusive, given in Table No. 5, were made to test the result previously given by Experiments Nos. 35 and 36, and to regulate the spacing of the lattice bars and the thickness of metal in the channel bars.

In all these experiments the posts were placed horizontally in the press, without any intermediate guide or support, excepting a counterbalance in the centre, of about one-half their weight. The pressure, recorded by a mercurial gauge, was applied by increments of from 1000 to 2000 pounds per square inch of sectional area of column, and completely released between each application.

The vertical and lateral deflection and the compression of the column under each application of pressure and its permanent deformation after each release were carefully measured.

Figures 1 to 4, Plate XXIX, show the apparatus used for measuring the compression.

A brass frame F, bears a lever $m\ l\ n$, the long arm of which commands, by means of rod $m\ v$, a vernier, v, moving on a graduated inch scale $g\ r$. The small arm bears an articulated rod $n\ p$ forked at the loose end p. Two footings, $S\ S$, at the bottom of frame F, allow of its being fastened by means of clamp screws on to a wooden bar $A\ B$, made fast at one end

to flange *f f* of column by clamp *C*, and moving freely at the other end through clamp *D* as a guide. Clamp *D* is fastened to the flange of the column at such a distance from frame *F* as will allow the forked end of rod *n p* to bear on a small pin *p*, borne by clamp *D*.

A small weight *W*, maintains the contact at *p*. The distance moved by point *p* being the compression of the length *L* of column between clamps *C* and *D* is multiplied ten times on scale *g r*, the vernier reading the $\frac{1}{200}$ of an inch, the compression is observed to the nearest $\frac{1}{2000}$ of an inch, which for a length of twenty feet and a modulus of 24 000 000 corresponds to a pressure of fifty pounds per square inch.

After all parts had been brought to a good bearing by the first application of pressure (from five to eight thousand pounds per square inch) there was generally no permanent deformation observable until a pressure had been reached of about 15,000 pounds per square inch for the long columns, when a slight permanent set in deflection and compression would usually appear simultaneously and increase gradually until the crippling point was reached, when the column would yield faster than the pressure could be maintained by the pump.

The compression of the column during the period of perfect elasticity was carefully noted and used for the determination of the modulus. The modulus thus obtained is undoubtedly somewhat smaller than the modulus of the metal, a part of the observed compression being due to the bending of the column, but this error of observation being nearly the same for all columns of the same length, does not affect materially the comparison of the results. The same may be said of the influence of the neglected friction of the plunger, and of the vibration due to the close proximity of heavy working machinery in the shops where the experiments were made.

These experiments, although very incomplete, and made under somewhat unfavorable circumstances, have enabled me to accomplish substantially the object for which they were instituted, viz.: the proportioning of the compression members in the structures built by different contractors with the same margin of safety, and they have led me to the following conclusions. derived from a careful comparison of results obtained.

1st.—As between Rankine's and Gordon's formulæ, Rankine's is the more accurate of the two. This is shown by the results of the tests on the Phœnix and closed square posts (tables 3 and 4), where the parts being

Apparatus to measure Compression and Extension of Wrought-Iron Columns and Tie-Bars under strain.

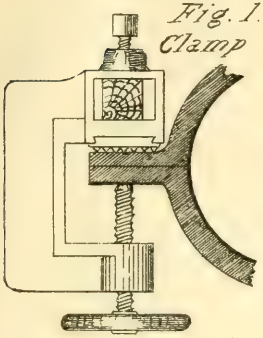


Fig. 1.
Clamp C.

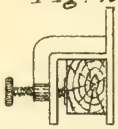


Fig. 2.
Fastenings S S

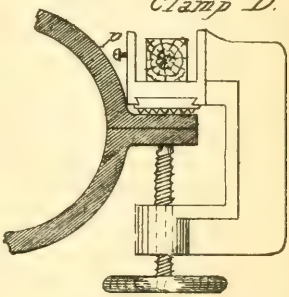


Fig. 3.
Clamp D.

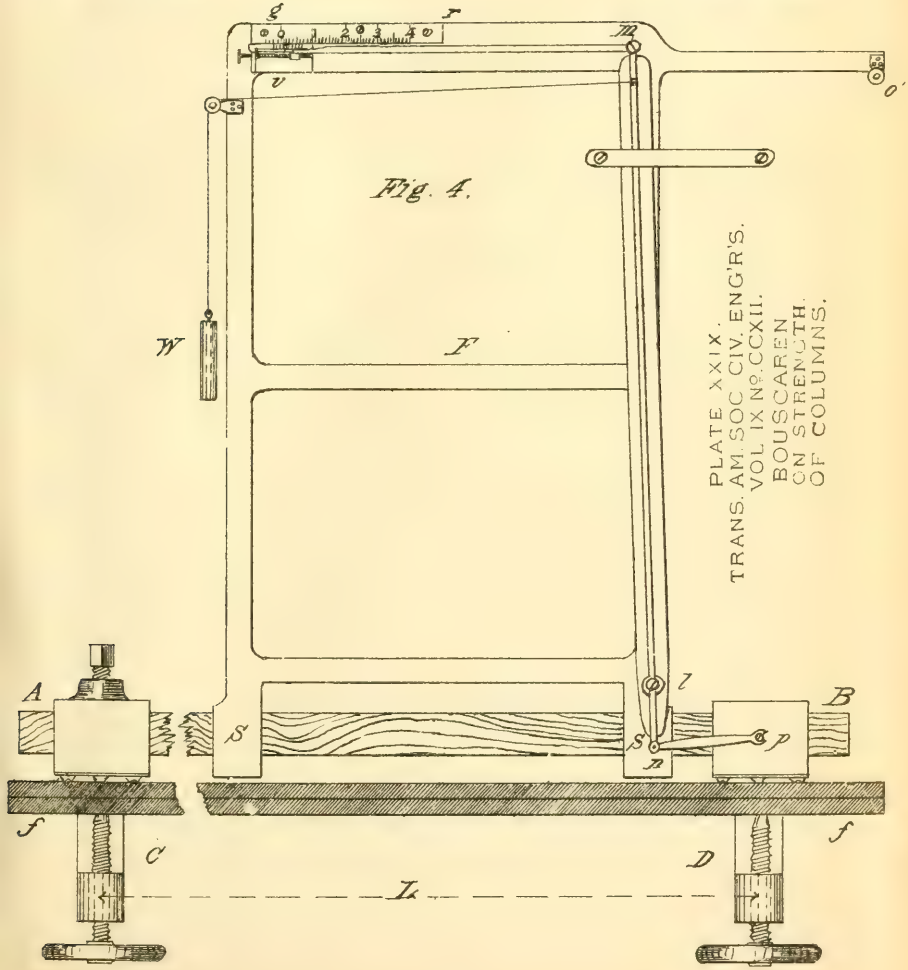


Fig. 4.

PLATE XXIX.
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. IX. No. CCXII.
BOUSCAREN
ON STRENGTH
OF COLUMNS.

thoroughly united together, the large factor due to defective construction and workmanship may be considered as eliminated in a great measure. These results compare as follows :

EXTREME VALUES OF CONSTANTS OBTAINED FOR PHŒNIX POSTS WITH FLAT ENDS.

	Rankine.	Gordon.
Largest value	49 400	57 500
Smallest value	41 100	43 700
Difference	8 300	13 800
	Less than 17 %.	More than 22 %.

EXTREME VALUES OF CONSTANTS OBTAINED FOR SQUARE CLOSED POSTS WITH FLAT ENDS.

	Rankine.	Gordon.
Largest value	39 800	47 300
Smallest value	38 300	39 800
Difference	1 500	7 500
	Less than 4 %.	More than 15 %.

2d.—Iron of the highest modulus does not necessarily make the strongest column.

This conclusion, which is at variance with the opinion entertained by many engineers, is shown in a remarkable manner by the same experiments on the Phœnix and closed square posts, where not only do the values of constant "f" fail to follow any proportional relation to the corresponding moduli, but the greatest value of "f" obtained for the Phœnix posts actually corresponds to the smallest modulus. It is proper to state here that although the average moduli of the Phœnix and square posts were very nearly the same, the iron in the two kinds of posts differed widely as to other characteristics, the Phœnix iron being a very close-grained, fibrous and hard metal, whilst the iron of the square posts was comparatively soft and of a coarser texture, which explains the difference in the average values of "f" obtained for these two kinds of posts.

3d.—It is essential in built columns to thoroughly fasten together the several parts or segments that they may act in a solidary manner as one

continuous metallic body, and to guard not only against lateral flexure or buckling of each part, but also against longitudinal relative motion.

The importance of these conditions is demonstrated by the great variation in the results of tests of columns of the same length and shape, made of the same quality of iron, but differing in the fastening together of their several parts, as shown by experiments 3 and 8, and 25 and 31, Table No. 1, where the substitution of close riveting at the ends in place of cast shoes bolted on, made a difference of 22 % and 17 % respectively in the strength of the columns.

The anomalous results of tests Nos. 19 and 41, Tables Nos. 2 and 5, where the columns failed by flexure in the direction of the largest radius of gyration are also due, very probably, to the insufficiency of the riveting.

4th. A due regard to the economy of material demands that the thickness of the metal, and in built columns, the spacing of the rivets be so proportioned that the column shall fail by flexure, as a whole, before any local buckling or flexure shall take place.

This is well illustrated by experiments Nos. 37 to 42, inclusive, Table No. 5, instituted for the purpose of determining the largest spacing of rivets and the smallest thickness of metal allowable for a particular style and length of post. Columns Nos. 37 and 38, having both failed by the buckling of the metal in the channel, and the local flexure of the channel between rivets, pieces of channels were tested of the same shape and sectional area as those used in the posts, and of lengths equal to the distance between the lattice rivets ; they failed in the same manner as the channels had failed in the long columns, but under somewhat higher pressure per square inch, confirming the first results.

Column No. 41, in all respects similar to Nos. 37 and 38, but with thickness of metal slightly increased and spacing of rivets reduced to 20 inches, was then tried and failed by the simultaneous flexion and buckling of the metal in the channel and the bending of the column bodily, showing that the column was properly proportioned, being of equal strength in all its parts.

Test No. 42 confirmed No. 41, and it was established that for that ratio of length to diameter the thickness of the metal should not be less than $\frac{1}{30}$ of the distance between supports transversely, which confirms Fairbairn's rule, and that the distance between rivets longitudinally should be such that the length of channel spanning it, considerd as a

column, and calculated by Rankine's formula, shall give the same resistance per square inch of area as the column itself treated in the same manner with the same constant "*f*."

5th. It may be concluded from experiments Nos. 13, 14, 16, 17, 21, 36 and 43, made with columns hinged on pins at both ends, that Rankine's formula with constant "*a*" assumed at double its value as applied to columns with flat ends, is practically correct, the variations in the values of "*f*" derived from these tests, being probably attributable, in a large measure, to the difference in the fitting of the pin, a "close fit" giving invariably higher results, the friction resisting, of course, the tendency to flexion.

The very large variation of the calculated value of "*f*" for Nos. 36 and 42 must, however, be ascribed to another cause, viz.: the now well established property of iron, that its limit of elasticity is increased after the metal has been once subjected to a strain beyond its limit of elasticity and then allowed to rest. This circumstance accidentally occurred for column No. 36, as explained in the marginal note in the table.

Tests No. 6 and 18, Tables Nos. 2 and 3, were also made on columns which had previously been strained beyond their elastic limit, and further confirm the same property.

Many important questions concerning wrought iron columns as used in our modern structures remain to be elucidated by direct experiments.

It would be useful to test:

1st. The effect of the eccentricity of the line of pressure to the axis of the column which occurs frequently through the unequal tension of tie-bars.

2d. The effect of a force acting transversely to the axis of the column. This occurs as a rule in all horizontal or inclined compression members, and in all posts riveted to floor beams.

3d. The applicability of the Rankine formula to the tiers of a long column guided at intervals, as is the case for the continuous posts of high trestles and piers held in line by the systems of horizontal and vertical bracing, the tiers being assimilable to neither flat nor pin-end posts.

4th. The influence on the strength of a long post, of the support afforded by a stiff but yielding web, as it occurs for the top flange of plate girders and the top chord of partly over-grade trusses.

In this line of investigation our large bridge contracting firms

should take the lead. They have at hand the facilities for conducting leisurely and methodically such experiments. The contractor and the engineer should join hands in an endeavor to reduce from *six* to *five* or even *four*, the irrepressible "factor of safety" invented to cover two large fields, the "incidental" and the "unknown," the limits of which should gradually contract under the light of well observed facts.

Experiments on Wrought Iron Columns

Table N°1. Keystone Columns.

N°	Date and Place of Testing	Place of Manufacture of Iron	Kind	Cross Section at Centre	Length	Ratio of Length to Diameter	Distance from centre to centre of rivets -in.-	Sectional Area -sq.in.-	Square of Radius of Gyration Unit=1 inch	Limit of Elasticity -lbs.-	Resistance per sq.in. -lbs.-	Modulus of Elasticity	£ by Gordon's Formula	£ by Rankine Formula	Remarks.
1	April 19th 1875.	Pittsburgh Penn.	Union Iron Mills Pittsburgh Penn.	Flat ends-closed.		0'-9"	1.1	5	14.25	———	———	45,000 (1) 57,500 (2)	———	———	———	Planed at both ends. No shoes. Rivetted through flanges Failed by buckling of iron in all segments (1) Signs of buckling (2) Crushing past
7	April 27th 1875	do	do	do		15'-0"	21.7	6	14.62	9.206	17,500	30,000	23,800,000	34,700	32,900	Planed at both ends. No shoes. Rivetted through flanges Failed by deflection
9	April 28th 1875	do	do	do		15'-0"	20.3	6	23.67	7.833	19,000	32,000	24,700,000	36,400	35,700	Planed at both ends. No shoes. Rivetted through Flanges With cross plates between flanges Failed by deflection
27	July 31st 1875	do	do	do		27'-0"	37.6	12	18.83	9.798	18,000	27,800	23,700,000	40,800	36,000	Planed at both ends. No shoes. Rivetted through flanges Iron soft and badly welded in rolling Failed by deflection downward
24	July 2nd 1875	do	do	Flat ends-open-straight		27'-0"	34.1	12	19.20	12.041	15,000	25,000	26,500,000	34,700	31,100	Rivetted diametrically between flanges End fitted with diagonal plates and planed Failed by deflection sideways.
26	July 31st 1875	do	do	do		27'-0"	34.6	12	14.49	11.178	17,000	27,500	27,500,000	38,400	34,700	Rivetted diametrically between flanges Fitted with square castings bolted at ends Failed by deflection downward
30	Aug 5th 1875	do	do	do		27'-0"	34.1	12	15.13	11.464	12,000	30,000	19,300,000	42,100	37,600	Rivetted diametrically between flanges Ends planed. No shoes Failed by bending downward & sideways
2	April 19th 1875	do	do	Flat ends open-swelled		5'-0"	6.5	15	14.25	11.044	———	33,600	———	34,700	33,900	Rivetted diametrically between flanges Fitted with square castings bolted at ends Failed by buckling between rivets
3	April 19th 1875	do	do	do		15'-0"	19.5	15	14.84	10.834	———	28,800	34,600,000	32,400	31,200	Same as N° 2 Failed by deflection
8	April 26th 1875	do	do	do		15'-0"	20.0	15	14.80	10.353	15,000	36,900	29,600,000	41,800	40,100	Rivetted diametrically, ends planed and rivetted with cross plates & angle irons. Failed by buckling between rivets
4	April 20th 1875	do	do	do		27'-0"	35.2	15	12.96	10.883	16,700	24,100	———	34,100	30,600	Same as N° 2 diameter at ends 9.2" Failed by deflection
25	July 31st 1875	do	do	do		27'-0"	33.7	12	18.83	11.424	12,000	21,100	28,100,000	29,100	26,500	Same as N°s 2 and 26 Failed by deflection downward
31	Aug 5th 1875	do	do	do		27'-0"	34.1	12	15.13	11.464	16,000	25,400	23,600,000	36,100	31,900	Rivetted diametrically between flanges Ends as for N° 30 Failed by deflection upward & sideways
5	April 21st 1875	do	do	Hinged ends open-swelled		27'-0"	35.1	15	13.12	10.945	15,000	22,000	29,500,000	40,100	33,700	Rivetted diametrically. Square castings at ends fitting on a pin, the whole length of the latter bearing against an abutting casting. Diameter of column at ends = 9.22" Failed by deflection.

Experiments on Wrought Iron Columns. — Table Nº 2 — American Bridge Co's Columns.

Nº	Date and Place of Testing		Place of Manufacture of Iron	Kind	Cross-section at Centre	Length	Ratio of Length to Diameter	Dist. fr. cen. to cen. of rivets in.	Sectional Area sq. in.	Square of Radius of Gyration (Unit=1in.)	Limit of Elasticity lbs.	Resistance per sq. in. lbs.	Modulus of Elasticity.	"f" by Gordon Formula	"f" by Rankine Formula	Remarks.
12	June 2nd 1875	Chicago Ills.	Cleveland Rolling Mills Cleveland O.	Flat ends.		20'-0"	25.3	8	20.10	8.653	15,000	———	———	———	———	Ends planed to fit squarely on abutting castings. Uneven bearings; test discontinued after a pressure of 19000 lbs. per sq. in. had been applied.
18	June 3rd 1875	do	do	do		20'-0"	25.3	8	20.10	8.653	23,000	31,500	23,600,000	37,500	37,300	Same column as Nº 12 tested a second time. Failed by bending sideways.
19	June 3rd 1875	do	do	do		27'-0"	34.1 (32.4)	8	20.10	13.510 (8.635)	24,000	27,800	32,900,000	38,600 (37,500)	33,700 (37,200)	Ends planed and rivetted as for Nº 12. Failed by bending upward. {The numbers between parenthesis apply to bending sideways}
15	June 3rd 1875	do	do	do		30'-0"	45.0	8	14.97	5.388	13,000	23,700	26,000,000	39,700	39,500	Ends as for Nº 12. Column balanced at center with 500 lbs. Failed by bending sideways.
16	June 3rd 1875	do	do	Hinged ends		20'-0"	30.0	8	12.50	5.479	15,000	26,700	28,900,000	42,700	42,300	Ends Hinged as for Nº 13. Failed by bending sideways.
17	June 3rd 1875	do	do	do		20'-0"	24.0	8	19.90	8.733	12,000	26,500	23,100,000	36,700	36,200	Ends Hinged as for Nº 13. Failed by bending sideways.
13	June 2nd 1875	do	do.	do		26'-0"	29.0	8	25.05	18.215	12,000	24,000	30,400,000	37,500	37,100	Ends Hinged as shown. Failed by bending downward.
14	June 3rd 1875	do	do	do		26'-0"	31.2	8	20.72	8.733	14,000	22,000	26,000,000	36,300	35,600	Ends Hinged as for Nº 13. Failed by bending sideways.

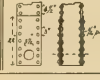
Experiments on Wrought Iron Columns.

Table Nº 3 Phœnix Columns.

Nº	Date and Place of Testing		Place of manufacture of Iron	Kind	Cross-section at Centre	Length	Ratio of Length to Diameter	Dist. fr. centres of rivets in.	Sectional Area sq. in.	Square of Radius of Gyration (Unit=1 in.)	Limit of Elasticity lbs.	Resistance per sq. in. lbs.	Modulus of Elasticity	f' by Gordon Formula	f' by Rankine Formula	Remarks.
6	April 27th 1875	Pittsburgh Penn.	Phœnixville Penn	Flat ends		15'-0"	22.4	6	14.09	8.536	35,000	37,500	27400,000	43,700	41500	Planed at both ends, No shoes, had been compressed previously. Failed by bending.
10	June 2nd 1875	Chicago Ills.	Phœnixville Penn.	do		27'-0"	39.9	6	13.70	8.935	18,000	31000	29,100,000	47,400	41,100	Ends rivetted closely and fitted with square castings as shown. Failed by bending.
28	Aug. 5th 1875	Pittsburgh Penn.	Phœnixville Penn.	do		28'-0"	40.7	6	13.58	8.935	22,000	34,800	25,700,000	54,600	47,000	Ends rivetted closely and planed, Balanced at center with 650 lbs. Failed by bending downward.
29	Aug. 5th 1875	do	Phœnixville Penn.	do		28'-0"	40.7	6	13.58	8.935	18,000	36,600	28,500,000	57,500	49,400	Ends planed and rivetted closely. Balanced at center with 650 lbs. Failed by deflection upward.
11	June 2nd 1875	Chicago Ills.	Phœnixville Penn.	Ends Rounded With large Radius		27'-0"	39.9	6	13.89	8.935	17,000	21,700	27,100,000	(1) 44,700 (2) 67,700	(1) 35,900 (2) 50,000	Ends closely rivetted and fitted with spherical abutting castings. Failed by bending. (1) By formula for Hinged ends. (2) By formula for Round ends.

Experiments on Wrought Iron Columns.

Table Nº 4 — Square Columns.

Nº	Date and Place of Testing		Place of manufacture of Iron	Kind	Cross-section at Centre	Length	Ratio of Length to Diameter	Dist. betⁿ centres of rivets in.	Sectional Area sq in.	Square of Radius of Gyration (Unit=1in.)	Limit of Elasticity lbs.	Resistance per sq.in. $\frac{P}{S}$ lbs.	Modulus of Elasticity	"E" by Gordon Formula	"E" by Rankine Formula	Remarks
23	June 29th 1875	Chicago Ills.	Pencoyd Iron Works near Philadelphia Penn.	Flat ends		24'—0"	34.1	4	13.70	11.628	15,000	33,200	28,900,000	46,100	39,800	Column from the Baltimore bridge Co. Twisted before test 7/8". Ends planed, column balanced at center with 300 lbs. Failed by bending downward, plates buckled.
22	do	do	Ohio Falls Iron Works New Albany Indiana	do		26'—0"	41.6	4¼	13.60	9.347	16,000	30,000	27,800,000	47,300	38,700	Column from the Louisville bridge Co Ends planed and closely rivetted, column balanced at center with 300 lbs. Failed by bending upward.
32	Aug. 26th 1875	Pittsburgh Penn.	Union Iron Mills Pittsburgh Penn.	do		27'—0"	30.9	6	26.05	10.909	15,000	30,200	30,100,000	39,800	38,300	Column from the Keystone Bridge Co. Ends planed Failed by bending sideways.
21	June 29th 1875	Chicago Ills	Ohio Falls Iron Works New Albany	Hinged ends		25'—9"	30.9	4½	13.60	11.000	18,000	25,500	31,000,000	41,700	37,800	 Colum from the Louisville bridge Co. Castings as for Nº 14 (Table Nº 2) Column balanced with 300 lbs. at center Failed by bending sideways.

Experiments on Wrought Iron Columns.

Table No. 5. Open Columns.

No.	Date and Place of Testing.		Place of manufacture of iron	Kind	Cross-section at centre	Length	Ratio of length to Diam.	Distance from cen. to cen. of Rivets In.	Sectional Area. Sq. in.	Square of Radius of Gyration (Unit = 1 in.)	Limit of Elasticity lbs.	Resistance per sq. in. $\frac{P}{A}$ lbs.	Modulus of Elasticity	"f" by Gordon Formula	"f" by Rankine Formula	Remarks.
20	June 3rd 1875	Chicago Ills.	Cleveland Rolling Mills Cleveland, O.	Pin Ends		10'-0"	15.0	——	9.66	10.90	8,000	20,000	27,600,000	23000	21400	Broke by deflection downward Defective Construction.
33	Nov. 22nd 1875	Pittsburgh Penn.	Cleveland Rolling Mills, Cleveland O.	do		28'-6⅛"	34.24	18"	5.68	20.07	21,100	31700	32,400,000	56,500	42,000	Broke by deflection upward and sideways and by buckling of angles between lattices. Angles fractured at one end near plates and near middle of strut.
34	Dec. 4th 1875	Chicago Ills.	Ohio Falls Iron Works New Albany Indiana	Flat Ends		12'-3"	18.37	——	6.00	18.06	16,000	17,600	——	19,600	18,200	Broke by deflection upward Defective construction.
35	May 31st 1877	Louisville Ky.	Union Iron Mills, Pittsburgh Pa.	Pin Ends		34'-0"	51.00	22¼"	7.48	8.73	8,800	20,053	——	——	——	Column balanced by 635 lbs. gave way by pin crushing and splitting web of channel column but injured otherwise No permanent set in deflection. Permanent set in compression for 34 ft = 0.121 in.
36	June 2nd 1877	do	do	do	Same as No. 35	34'-0"	51.00	22¼"	7.48	8.73	21,600	23,128	——	63,100	47,600	Column No. 35 tested again after crushed ends had been cut off and thickning plates rivetted on with pin holes 34" from center to center. Column failed by deflection downward
43	Feb'y 18th 1879	Pittsburgh Penn.	do	do		26'-6½"	45.5	20"	6.50	5.95	12,000	18,000	——	42,800	35,049	Counter balanced at centre with one half its weight. Failed by bending sideways at right angles with pins, without buckling of metal.
37	Dec. 23rd 1878	do	do	Flat Ends		27'-5 11/16"	27.47	24	12.078	19.98	——	29,600	——	38,000	34,094	Web buckled in both directions, in middle and at one end of column, column did not bend.
38	Dec. 30th 1878	do	do	do		23'-0⅛"	23.01	21	13.476	20.69	23,000	32,300	——	38,000	35,626	Column balanced with 640 lbs. at center. Failed by buckling of web at both ends and at middle, same as No. 37 and by column deflecting downward simultaneously.
39	do	do	do	do		24"	8.53	——	6.6	0.7	——	35,400	——	36,200	35,264	Sec. ab Sec. ef Failed by buckling of web and flanges as shown.
40	do	do	do	do	Same as No. 39	19 5/16"	6.86	——	6.6	0.7	——	35,700	——	36,400	36,415	Sec. ab Sec. cd Failed by buckling of web and flanges as shown.
41	Feb'y 18th 1879	do	do	do		27'-6"	27.50	20	13.74	20.79	20,800	32,400	——	40,600	37,174	Column built the same as No. 37 with lattices spaced 20" instead of 24", balanced at center with one half its weight. Failed by buckling of web as for No. 37 and by bending downward and sideways simultaneously.
42	do	do	do	do		27'-6"	+33.0 25.4	18	11.052	+13.43 21.26	21,000	32,300	——	+44,100 39,300	+39,632 36,949	Balanced by one half its weight. Failed by deflecting upward without buckling of metal.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCXIII.

(Vol. IX.—December, 1880.)

THE IMPROVEMENT OF THE HARBOR OF QUEBEC.

BY J. VINCENT BROWNE, C. E.

READ SEPTEMBER 1ST, 1880.

Fortunately for Quebec, two great undertakings immediately connected with its future prospects, are now so far advanced as to demonstrate to some extent the purpose for which they were intended.

The North Shore Railroad is complete, and doing a fair amount of business, transporting lumber of all dimensions to this place. This railway and the improvements of the harbor will form an important factor in the prosperity of Quebec.

The great width of the St. Lawrence river at Quebec and its almost perpendicular rocky fore-shore, the unusual depth of water in places close in shore, with strong currents and the great rise and fall of the tide, render it necessary that some sort of harbor of refuge should be provided, so that vessels under detention or late in arriving can winter here in safety. Access to deep water at all stages of the tide must also

be provided for the carrying trade opened by the North Shore Railroad.

The immediate vicinity of the mouth of the St. Charles river was selected for commencement of the present Harbor Improvements, which are now rapidly approaching completion.

Knipple & Morris, of London, England, are the designing engineers, but the works are under the immediate supervision of Woodford Pilkenton, also of London, England, all of whom are members of the Institution of Civil Engineers. The contract for these works was awarded to Simon Peters, of Quebec, Edward Moore, of Portland, Maine, and Augustus R. Wright of New York City. The contract holds the contractors responsible for the work and its maintenance for a period of twelve months after its final completion. It also requires the contractors to furnish a competent engineer to take charge and generally superintend the entire work.

Work was commenced in the fall of 1877, but little was then accomplished. During the succeeding seasons of 1878-9, rapid progress has been made. The work at present in progress of construction could form a centre embankment for a double wet dock, as well as a double tidal harbor, but one of each is all that is now contemplated. See Plate XXX.

The present embankment forms the northern wall, and the fore-shore the southern wall of the wet dock and tidal basin ; the west wall of the wet dock is formed by Gas House Wharf, and the east wall by the cross-wall, which latter forms the west wall of the tidal harbor.

This embankment is named, "The Princess Louise Embankment." It has a length from east to west of 3 500 feet, a height above low water, of 24 feet, and extends from Gas House Wharf to, and forms a junction with what has been for some years an isolated mole or breakwater, which stands in 50 feet of water at low tide, and is known as Ballast Wharf.

The south wall of the Louise Embankment, which is the north wall of the tidal harbor and wet dock, is nearly complete and is to be for its entire length a cut stone superstructure resting on a foundation of timber cribwork and concrete filling.

The north wall of the embankment is formed by a continuous (entremese filling) cribwork, with counterforts at intervals of every 20 feet, extending into the embankment 22 feet.

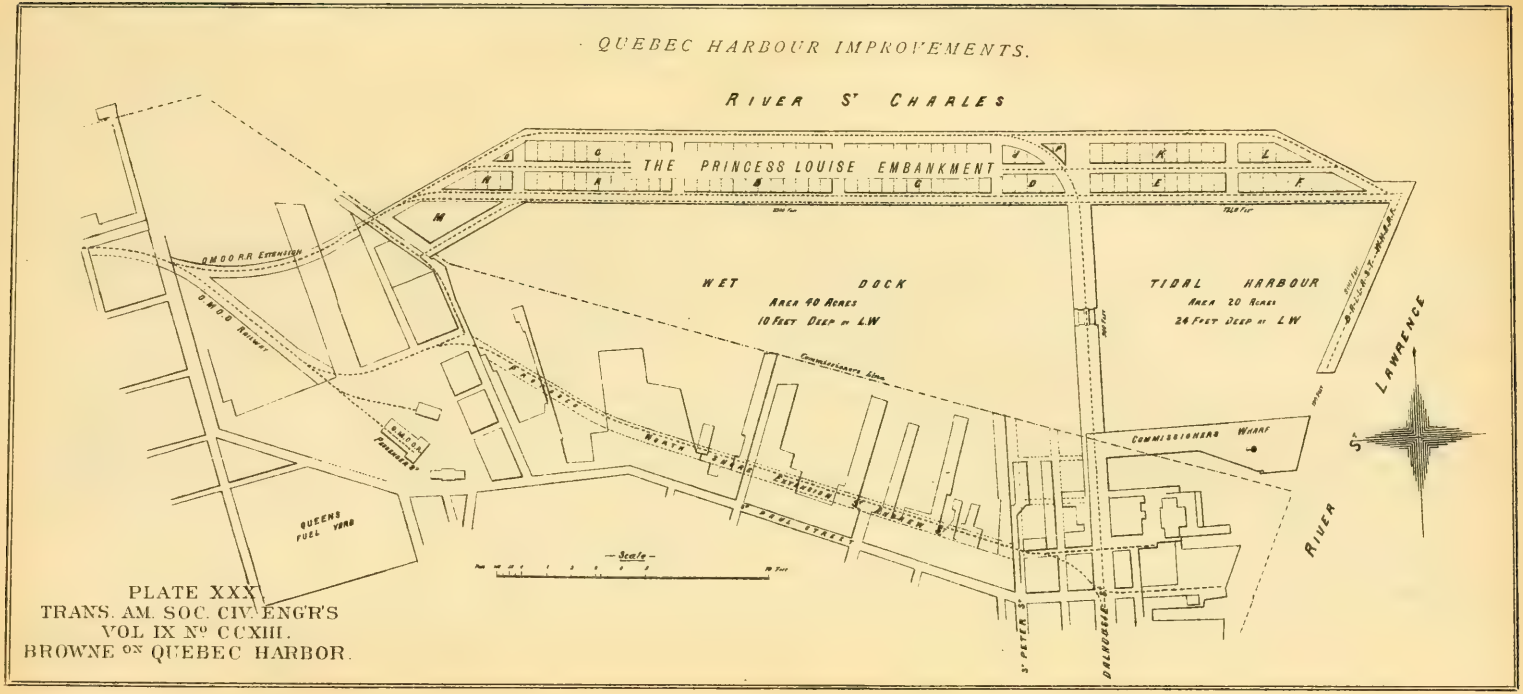


PLATE XXX.
TRANS. AM. SOC. CIV. ENG'RS
VOL IX N^o CCXIII.
BROWNE ON QUEBEC HARBOR.

PLATE XXXI.
TRANS. AM. SOC. CIV. ENG'RS
VOL. IX. No. CCXIII.
BROWNE ON QUEBEC HARBOR.

On final completion of this embankment there will be added to the length of the wharf accommodation of this port upwards of one and a half miles. The entire water area inclosed is sixty acres.

The works have already demonstrated their value as a protection to shipping, as not a dollars worth of damage has been sustained by the vessels within them last winter, although the ice was heavy. All the crowding and shoving that has taken place in former years, is now done away with.

The value of floating property wintered within the limits last season was upwards of two hundred and fifty thousand dollars.

There is now under consideration a steam ferry, for the purpose of transferring cars from the terminus of the North Shore Railroad, which is at the east extremity of the Louise Embankment to the opposite shore, or the Point Levis side of the St. Lawrence river, thereby giving through connection from the west to Halifax, Portland, Boston and New York.

For the foundations of the north wall of the wet dock and tidal basin a preliminary channel was dredged 150 feet in width, for 1 240 feet in length, to a uniform depth of 24 feet at low water ; the remaining 2 310 feet, which falls inside the wet dock, was dredged to a depth of 10 feet at low water. No serious impediment was encountered, except the great rise and fall of the tide, which averages 18 feet, the spring tides often running as high as 22 and 23 feet. The work of dredging was pushed night and day.

The foundation for the quay wall of the tidal basin, is formed by a series of timber cribworks in lengths of 120 feet each, of the name and style known as entremese filling. (See Plate XXXI for front view, Plate XXXII for back view, Plate XXXIII top view on section of crib, and Plate XXXIV end elevation of crib). The dimensions of these cribs are, length, 120 feet, width at base 33 feet, width on top 23 feet, and in height 27 feet, batter of face one-half inch to the foot. Plate XXXIII shows the pockets formed in the front of the cribs by a series of planking, which form the rear retaining wall for the concrete facing of foundation. Each second crib that is sunk is provided with a bulkhead, at its west end, or at the end where the next crib sunk will join. This bulkhead prevents any current in the pockets during the rise and fall of the tide, and also gives comparatively still water in which to deposit the concrete, thereby guarding against any possible wash of the concrete after being

deposited. The back of the cribs immediately in the rear of the pockets (see Plate XXXIV) is filled with stone and clay, in nearly equal portions, allowing it to take its natural slope. The filling taken with the concrete face forms a most substantial foundation. The amount of concrete in each length of 120 feet is 1 650 cubic yards (equal to 2 475 tons), and of clay and stone filling 2 723 tons, so that the dead weight actually placed with care in each crib is 5 198 tons.

The dredged material is then filled in over this clay and stone filling to a level of one foot below the concrete.

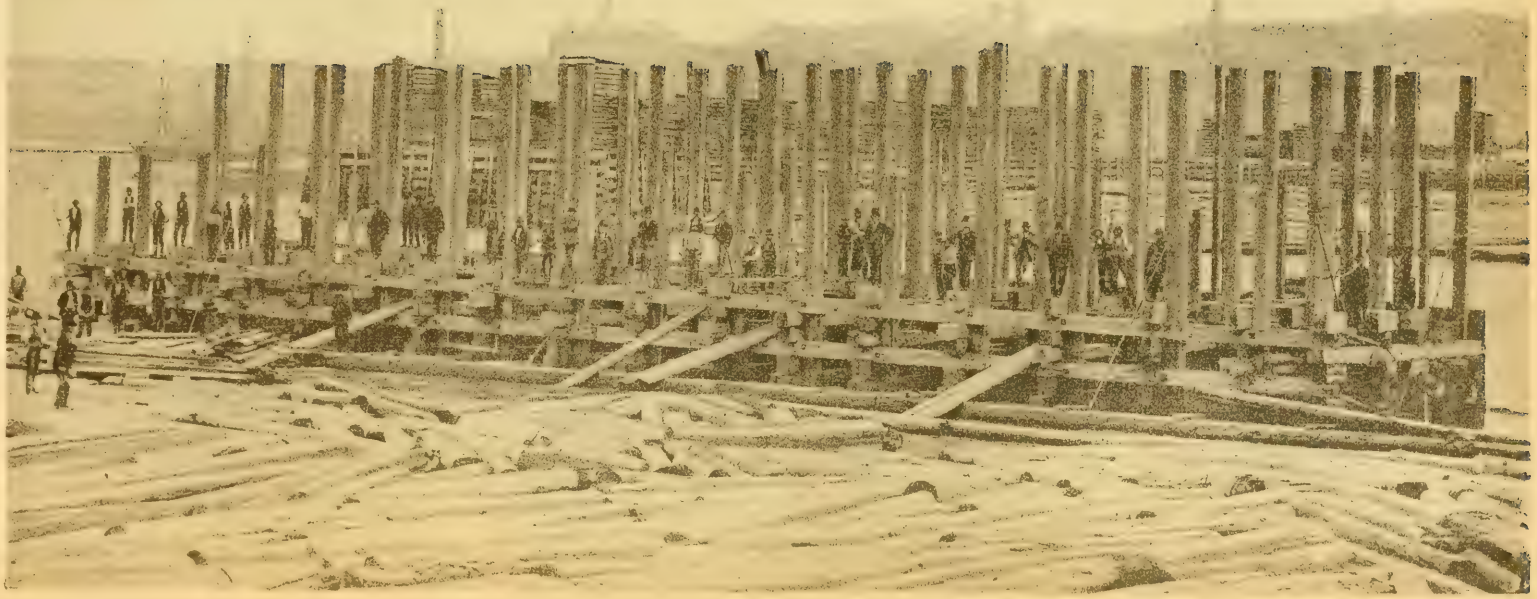
This style of foundation is 1 240 feet long, and all falls within the tidal basin. The remaining 2 310 feet of foundation, or that portion which falls within the wet dock (see Plate XXXV) is formed of skeleton cribs, with plank forming the back of pockets, the same as in the tidal harbor, while the face of the cribs is formed by sheet piling. These cribs are brought up to the piles and then filled with concrete, stone and clay filling and backing.

These foundation cribs, in all instances, rest on a series of stub piles driven to a uniform level by means of a follower, and in no instance are these piles allowed to project above the surface of the bed of the channel over 12 inches. Four submarine divers have been employed, as with the great depth of water it would be impossible to secure a level bottom and remove various obstructions without their aid.

The mode of placing the concrete within the crib foundations is by a skip, or box holding 1 cubic yard (see Plate XXXVI). This skip is an invention of Edward Moore, and is covered by letters patent. It is made of boiler plate iron, is 3 feet square and 5 feet in height, and is provided with double doors as a cover. The lower part of this skip also has double doors, about two feet from the bottom, held in position by a strong spring latch, to which is attached a line, so as to spring the latch at will. When the skip is lowered to the bottom the latch is sprung, and the concrete deposited and retained within its walls. The skip is then raised from it, leaving the concrete in block, with the least possible wash. This mode is employed for all under-water work.

The mixing of concrete is done by a machine similar to the one used on the jetty works at the mouth of the Mississippi river, but instead of its being a fixture it is placed on a scow 75 feet long, 30 feet wide and 7 feet sides, drawing about 3 feet of water. In connection with the mixer is a swinging crane, with a traveling truck on its top arm. The proper

PLATE XXXII.
TRANS. AM. SOC. CIV. ENGR'S
VOL. IX. Nº CCXIII.
BROWNE ON QUEBEC HARBOR.



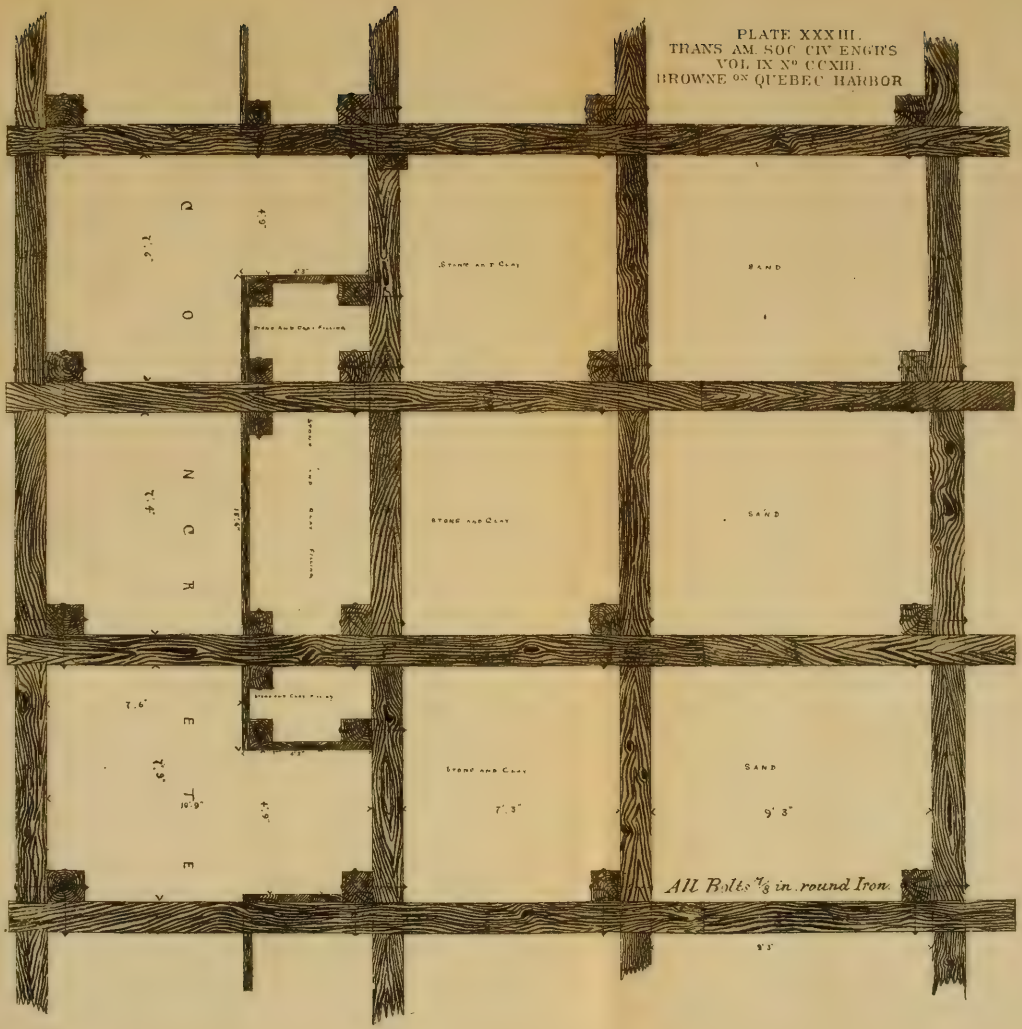


PLATE XXXIII.
TRANS AM. SOC CIV ENGRS
VOL IX Nº CCXIII.
BROWNE ON QUEBEC HARBOR
QUEEN
STREET
STONE AND CLAY
SAND
STONE AND CLAY
SAND
STONE AND CLAY
7' 3"
SAND
9' 3"
All Bolts 7/8 in. round Iron

portions of cement, sand and stone are placed in alternate layers, in an iron tub, and the requisite amount of water is deposited equally over the top of these, then it is hoisted up, and by means of a traveling truck, is run immediately over the hopper, which is directly over the mixer. The contents of the tub are dumped into this hopper, from which it passes into the mixer. Here it receives from 6 to 8 revolutions, when it is dumped into a car immediately underneath, the car is run out under the crane which handles the skip from the car. The concrete is placed in the skip, the crane swung around, and the skip run either in or out, at will. When in position it is lowered, and the concrete deposited in its place. By this appliance a uniform deposit is made, the mixer being hauled ahead or dropped back, at will, for the entire length of the work, thereby securing as nearly as possible uniform courses of concrete for the whole.

Owing to the great rise and fall of the tide, and to enable the work to continue at high water, or after the crib work is covered, traverses are secured to all angles of the rear planking, this forming a perfect profile of rear of the pockets, at the highest stage of the tide.

During the season of 1879, that is, from July until the 1st of November, there were placed in position by the mixer alone upwards of 9 000 cubic yards of concrete, and by hand 5 000 cubic yards. That placed by hand formed the backing of the cut stone superstructure, this requiring expert workmen.

The manner of bringing up the stone wall, and concrete backing, is as follows: A course of stone is first laid, which forms the front retaining wall. Plank, following the line of the planking in crib foundations, is then brought up for a back retaining wall, and the concrete placed in between the masonry and the planking. Great care is taken that at least 2 inches of fine material shall be secured between all the large stone placed in the concrete, as well as between them and the rear planking and the masonry. This concrete is finished off with each course of masonry laid, and large angular stones are left projecting from 4 to 12 inches above the concrete backing, and embedded at least 3 inches into it, this forming a perfect bond when the next course of concrete follows. As fast as the wall is carried up the filling in with dredged material is carried on, backing up the wall to within a reasonable distance from the top, so that no sand or silt may deposit itself upon the concrete during high water.

As the material dredged goes to form the embankment between the north and south walls, and as dump scows could only be used at certain stages of the tide, and then only to a limited extent, some rapid and economical means for conveying this material had to be employed. The difficulty was overcome by Messrs. Edward Moore and Augustus R. Wright, who jointly planned, constructed and patented a revolving derrick (see Plate XXXVII) with one arm on either side, directly opposite each other, each 110 feet long. This works in connection with a dipper dredge parallel to it, and 110 feet distant. From each arm of the derrick is suspended a tub of boiler plate iron of a capacity of 3 cubic yards. These tubs are swung alternately to the float on which they are landed at the dredge's side, the dredge raises its dipper, filled capacity, 3 cubic yards, swings it around, and dumps its contents into the tub.

The tub is then hoisted, the derrick swung around, and the contents of the tub dumped 210 feet from where it was dredged. And so the operation goes on day and night, moving about 1 500 yards per day. At first the derrick was carried on blocking, but it now rests on a pontoon, and is pulled ahead or dropped back at will.

Another portion of the material is moved by a clam-shell dredge, which travels on top of the northern wall of the embankment on a railroad track. This is employed in connection with a clam-shell dredge in the tidal basin.

The latter deposits its dredged material into scows which are run around outside and along the face of the northern wall, or cribwork, and dumped. Here the dredge on the embankment picks it up and deposits it inside the wall, thus forming the embankment.

The extent of dredging is about 1 000 000 cubic yards, and consists (see Plate XXX) of dredging the the tidal basin to a uniform depth of 24 feet at low water, and the wet dock to a uniform depth of 10 feet at low water, thus securing at all times 24 feet of water in the tidal harbor, and 10 feet in the wet dock, where formerly it was all dry land at low water.

At high tide there will be secured 37 feet of water in the tidal harbor, and when the gates are closed in the cross wall there can be maintained at all times 27 feet of water in the wet dock.

The plant used on the works has been 1 dipper dredge, capacity of bucket, 3 cubic yards; 1 revolving derrick same capacity; 1 clam-shell dredge, capacity of bucket, 2 cubic yards; 1 clam-shell hoister same capacity; 8 dump scows, capacity, 100 cubic yards each; 2 steam tugs; 4

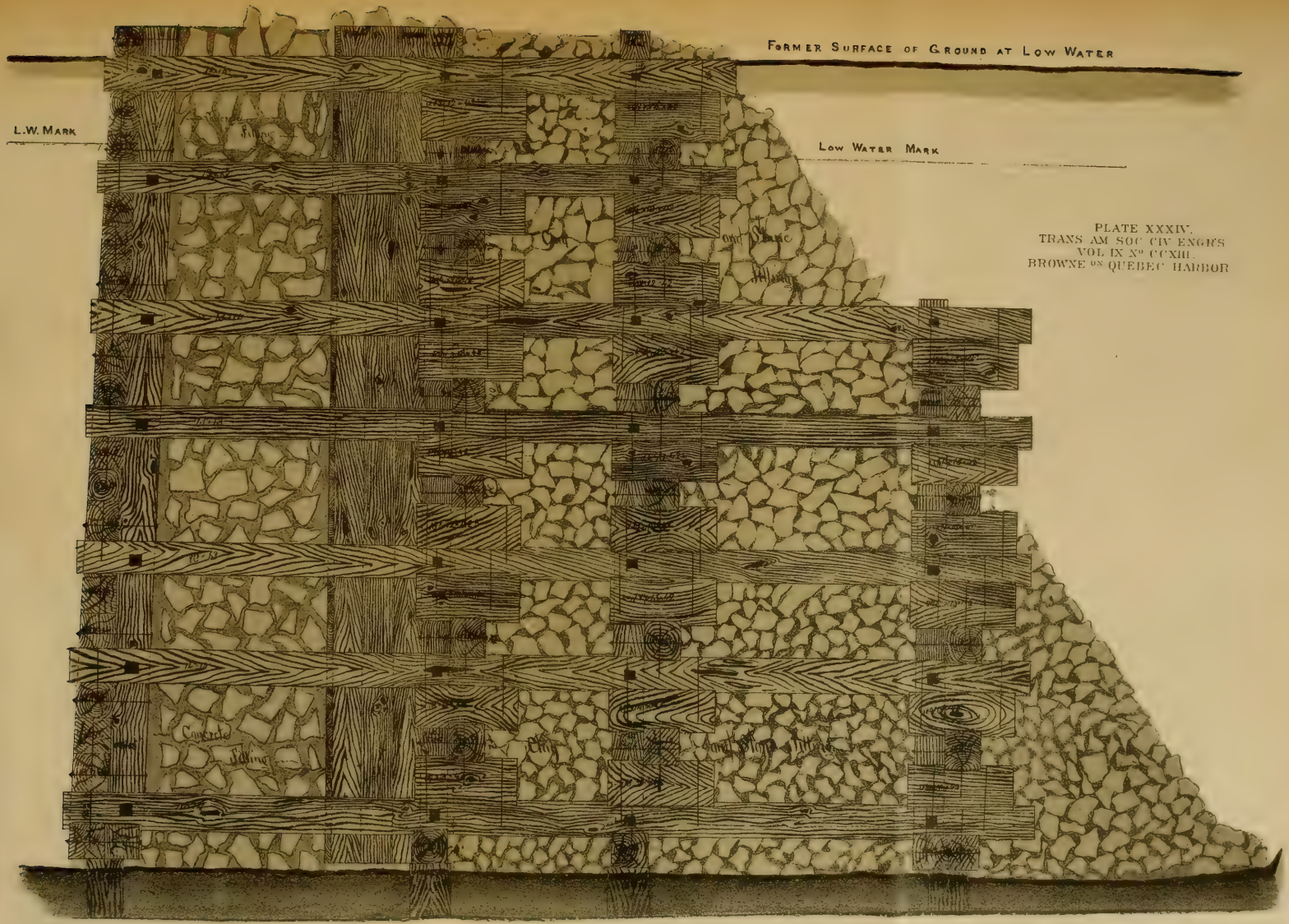
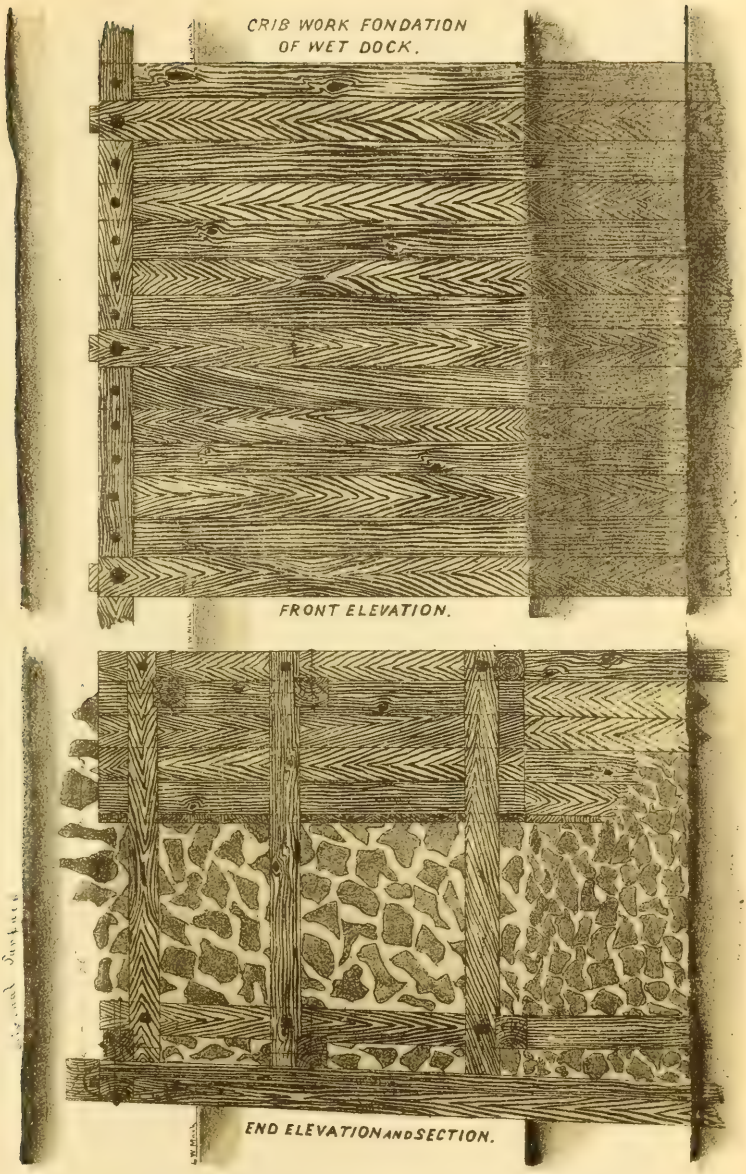


PLATE XXXIV.
TRANS AM SOC CIV ENGR'S
VOL IX N° CCXIII.
BROWNE ON QUEBEC HARBOR


CRIB WORK FONDATION
OF WET DOCK.
FRONT ELEVATION.
END ELEVATION AND SECTION.

deck scows; small steam hoister; steam concrete mixer; 3 pile drivers; 1 large barge (or cement store) beside numerous smaller craft for transporting supplies.

The concrete employed on these works consists of two kinds, eight to one and four to one. The former is composed of two barrels of clean, sharp sand, two of McAdam stone to pass a three-inch ring, four of large angular stone, and one of Portland Cement. The four to one concrete is composed of two barrels of clean, sharp sand, two of McAdam stone to pass a three-inch ring, and one of Portland Cement.

The cement used in these works is English Portland, manufactured by Gibbs & Co., London. Over 14 000 barrels have been used, all of which is subjected to a rigid test of its tensile strain, viz., 750 lbs. to a section of 1½ inches square.

One feature should be particularly noticed, which is that cement transported on steamers will not show such good results as that brought by sailing vessels.

In one instance, when a cargo by steamer did not come up to the standard, although tested several times, I caused it to be aerated for one or two days, keeping a man turning it over gently. The result obtained after this process was satisfactory, being above the required standard. Many experiments also prove that the smallest amount of water that can be used and yet make a good stiff composition, without sweating or weeping, gives the best results, as is shown by the following table :

No. of Bbl.	Oz. of Neat Cement.	Oz. of Water.	No. of Days in Water.	Tensile Strain 1½ in. sq.	Temperature.			Remarks.
					Air.	Water.	Cement.	
573	25	5½	7	840	57	54	58	
573	25	4	7	1060	62	58	60	Minimum of water.
572	25	5½	7	770	58	54	58	
572	25	5½	7	300	58	54	58	
572	25	4	7	980	62	61	62	Minimum of water.
572	25	4	7	950	62	61	62	Minimum of water.

It will be seen that by the use of the minimum amount of water, a

considerable gain in strength is obtained. For testing tensile strength a lever-balance machine is used, manufactured by Patrick Adie, London, England.

All of our briquettes have an area of 1½ square inches in the breaking section, but are sufficiently enlarged at the ends for the application of clamps.

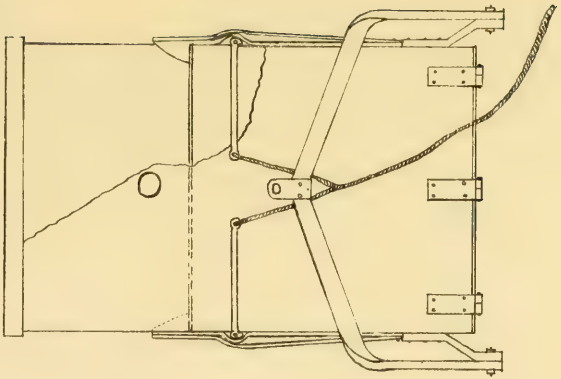
CONDENSED TABLE OF CEMENT TESTS.

Date. 1879.	The number of briquettes from which average is taken.	Tensile Strain.		Percentage passing sieve 2500 meshes per sq. inch.	Weight in pounds of Imperial struck bushel.	Average weight of bbls. in lbs.	Number of ounces of heat cement to each Briquette.	Average Temperature.			Average ounces of Water in each Briquette.
		7 Days in Water.	30 Days in Water.					Air.	Water.	Cement	
June.....	164	465.6	.....	82	116½	473	25	56.7	54.7	56.2	5.33
June.....	76	.....	525.2	"	"	"	"	56.7	54.7	56.2	5.33
July.....	194	528.04	608.32	"	115½	"	"	60.8	60.6	60.9	4.69
July.....	94	.....	608.32	"	"	"	"	60.8	60.6	60.9	4.69
Aug.....	164	573.84	.....	"	"	"	"	61.0	58.7	62.0	4.84
Aug.....	82	.....	646.6	"	"	"	"	61.0	58.7	62.0	4.84
Sept.....	156	565.2	.....	"	115¾	"	"	56.2	54.6	56.2	4.70
Sept.....	31	.....	651.2	"	"	"	"	56.2	54.6	56.2	4.70

By referring to Plates XXXVIII and XXXIX some idea may be had of the difficulty experienced in maintaining work in course of construction in so severe a climate.

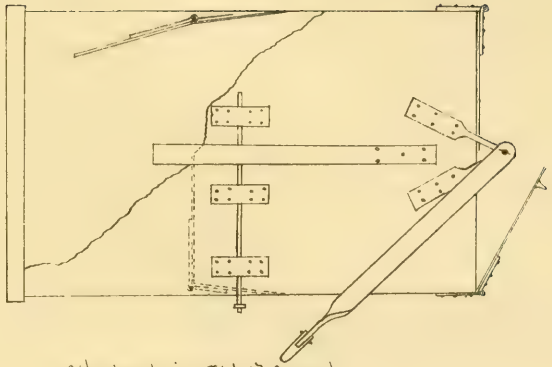
Plate XXXVIII shows a portion of the wall completed above reach of high water, to which is attached four feet in thickness of solid ice. This did not leave the wall until May 1st.

Plate XXXIX shows the immense body of ice resting upon the foundation of the wet dock wall, which is a continuance of the tidal basin wall shown in plate No. 10, again demonstrating the great difficulty that it has been to maintain the foundations through a winter season of six or seven months.



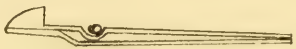
— Side view - showing trip-rods —

Concrete - Skip —



Side view - showing Catch & Cam-rod —

PLATE XXXVI.
TRANS. AM. SOC. CIV. ENG'R'S
VOL IX Nº CCXIII.
BROWNE ON QUEBEC HARBOR



Side view of Latch with cross-section of Cam-rod —

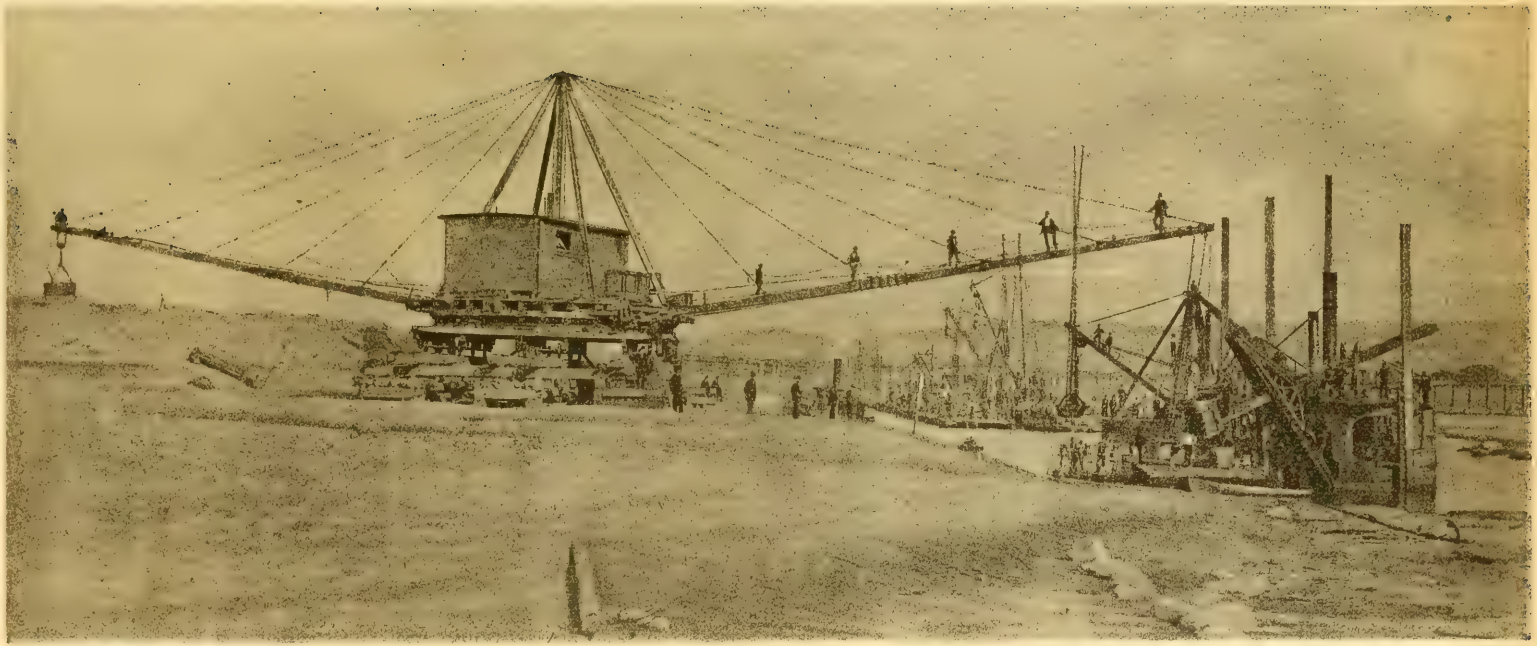


PLATE XXXVII.
TRANS. AM. SOC. CIV. ENG'RS

VOL. IX. N° CCXIII.
BROWNE ON QUEBEC HARBOR.

PLATE XXXVIII.
TRANS. AM. SOC. CIV. ENGRS
VOL. IX. No. CCXIII.
BROWNE ON QUEBEC HARBOR.

PLATE XXXIX.
TRANS. AM. SOC. CIV. ENG'RS
VOL IX N° CCXIII.
BROWNE ON QUEBEC HARBOR

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL VI.

JANUARY TO DECEMBER, 1880.

NEW YORK:
PUBLISHED BY THE SOCIETY.

1880.

Entered according to Act of Congress, by the AMERICAN SOCIETY OF CIVIL ENGINEERS, in the office of the Librarian of Congress, at Washington.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

INDEX.

Adams, Julius W.—On Committee, 2.—Paper by, 1.
Additions to Library and Museum. (See Library.)
— to List of Members. (See list.)
Allen, Horatio.—Discussion by, 10.
Allen, Theodore.—Discussion by, 50.—On Committee, 46.
Amendments to By-Laws. (See By-Laws.)
— to Constitution. (See Constitution.)
Anderson, Thomas S.—Admitted as Member, 18, 31.
Andrews, Edward R.—Discussion by, 58.
Announcements.—7, 15, 19, 29, 34, 54, 61, 63, 77, 85.—Annual Meeting, 85.—Catalogue of Library, 77.—Committee on Gauging Streams, 77.—De Lesseps, M., reception to, 15.—Institute of Mining Engineers, 15.—Metric System, 7, 15, 20, 21, 30, 35, 54, 61, 63, 77.—Nominating Committee, 77.—Proposed Amendments to the Constitution, 77.—Society House, 7, 15, 21, 31, 35, 54, 61, 63, 77.—Society Meetings, 61, 63, 77.—Twelfth Annual Convention, 7, 15, 19, 29, 34.—Twenty-eighth Annual Meeting, 85.
Annual Address, 45.
Annual Meeting, 83, 85, 89, 100, 104.—Change of date proposed, 49. (See Minutes.)
Annual Report of the Board of Direction. (See Board.)
Arch at Cohoes, by D. H. Van Auken, 113.
Armington, James H.—On Committee, 2, 18.
Arrears of Dues, 34, 58, 69, 108.

Ballard, Robert.—Admitted as Member, 69, 87.
Ballots for Amendments to Constitution, 9, 10.
— For Members, 1, 9, 18, 23, 33, 50, 58, 69, 83, 90.
— For Place of Convention, 1.
Barnard, John F.—Admitted as Member, 69, 87.
Baumann, Edward.—Admitted as Associate, 50, 55.
Baxter, George S.—Discussion by, 58.
Belcher, George C. W.—Admitted as Associate, 33, 55.
Bender, Charles.—Resignation of, 82.
Blaisdell, Anthony H.—Admitted as Member, 18, 21.—On Committee, 46.
Blunden, Henry D.—Transferred Junior to Member, 9, 35.
Board of Direction.—Report, 89, 90, 100, 101. (See Minutes.)
Bogart, John.—Discussion by, 18, 42, 50, 58, 98, 114.—Elected Secretary and Librarian, 90.—Makes report, 42, 100, 109.—On Committee, 2, 4, 9.—Reads Annual Address, 45.—Secretary of Convention, 37.
Boller, A. P.—Discussion by, 98.
Books on Engineering and Technology, List of.—11, 58.
Bouscaren, L. G. F.—Elected Director, 90.—Paper by, 69.
Bridges, Lyman.—Admitted as Member, 113, 125.
Bridges, The Use of Steel for, by Theodore Cooper, 90.
Briggs, Robert.—Discussion by, 23, 45.—On Committee, 45.
Brough, Redmond J.—Admitted as Member, 69, 87.
Browne, J. Vincent.—Paper by, 45, 69.
Brown, Robert N.—Resignation of, 16.
Brown, Thomas E, Jr.—Admitted as Junior, 90, 111.
Brush, Charles B.—Discussion by, 42.—Paper by, 42.
Building Fund.—114.
Burr, William H.—Transferred Junior to Associate, 33, 55.
By-Laws, Amendments proposed, 49, 97.

Campbell, John C.—Discussion by, 18, 48.—Paper by, 2.—Presides at Meeting, 48.
Canals, Inter-Oceanic. (See Inter-Oceanic.) — Ship Locks. (See Locks.)

CARTWRIGHT.

Cartwright, R.—Discussion by, 98.
Catalogue of Library, 77, 105.
Cements, American, by F. O. Norton, 42.
— Tensile Tests of, and an Appliance for more Accurate Determinations, by D. J. Whittemore, 42.
— Uniform System for Tests of, Committee and Reports, 10, 34, 43, 89, 90, 110.
Chanute, O.—Annual Address by, 45.—Discussion by, 2, 10, 18, 23, 57, 85, 98.—Elected Vice President, 90.—On Committee, 57, 100.—Presides at Meeting, 1, 2, 10, 17, 23, 33, 57, 83, 90.
Chaphe, Andrew J.—Admitted as Member, 9, 16, 21.
Chesbrough, E. S.—Discussion by, 42, 50, 113, 114.—On Committee, 45, 49.
Chimbote Tunnels, Location of, by O. F. Nichols, 42.
Civil Engineers, Employment on Government Works, 49, 69.
Clarke, T. C.—Censor to award Norman Medal, 69, 91, 108.—On Committee, 49, 50.—Paper by, 23, 98.
Colburn, Warren.—Memoir of, 4.
Collingwood, Francis.—Discussion by, 48, 98.—Paper by, 42.
Columns, Crippling Strength of Wrought-Iron, by C. L. Gates, 42.
— Experiments on Wrought-Iron, by G. Bouscaren, 69.
Committee on Finance, Report, 44, 89, 90, 100, 109.
— Employment of Civil Engineers on Government Works, 49, 69,
— Gauging of Streams, 43, 77, 98.
— Library, 100.
— Local, at Twelfth Annual Convention, 45, 46.
— Nominations, 45, 77, 100.
— Permanent Quarters, 10.
— Preservation of Timber, 10, 34, 44.
— Tests of American Iron, Steel, and other Metals, 42, 43.
— Uniform Tests of Cement. (See Cements.)
— Wind Pressure, 45.
Committees, List of Reports of, 104.
Compton, A. G.—Discussion by, 98.
Comstock, Cyrus B.—Admitted as Member, 69, 87.

CONSTITUTION.

Constitution, Amendments adopted, 10.—Amendments proposed, 9, 77, 84, 89, 93, 94, 97.
Convention, Twelfth Annual, 1, 7, 15, 33, 34, 37, 104. (See Minutes.)
— Thirteenth Annual, 50, 90, 91.
Cooper, Théodore.—Award of Norman Medal to, 90.—Discussion by, 2, 45, 50, 58.—On Committee, 45.
Coryell, M.—Discussion by, 42, 57.—Paper by, 45, 57.
Couvreux, A., Jr.—Discussion by, 17.
Craven, Alfred W.—Memoir of, 24.
Croes, J. J. R.—Discussion by, 49, 50, 58, 73, 98.—Elected Treasurer, 90.—Makes report, 43, 98, 116.—On Committee, 41, 50, 100.—Resolution by, 50.
Crosby, Benjamin L.—Admitted as Junior, 50, 55.
Crosby, W.—Discussion by, 94.
Crowell, James Foster.—Admitted as Member, 113, 125.
Currie, Daniel McN.—Admitted as Member, 33, 54.

Davis, J. P.—Discussion by, 98, 113, 114.—Elected Director, 90.—On Committee, 100.—Presides at Meeting, 50.
Dauzat, V.—Discussion by, 10.
Day, G. Frederic P.—Admitted as Junior, 90, 111.
Death of Members. (See List.)
Defrees, Morris M.—Admitted as Member, 18, 54.
Dempster, A.—Discussion by, 50.—On Committee, 50.
Dickinson, P. P.—On Committee, 2.
Dirks, Justin.—Admitted as Honorary Member, 54, 58.—Discussion by, 10, 17.—Paper by, 17.
Dresser, George W.—Amendment proposed by, 96.—Discussion by, 23, 57, 95, 98.—Paper by, 33.—Presides at Meeting, 1.
Drummond, John M.—Aids in preparing Memoir, 4.
Dues, Arrears of, 54.

Eads, James B.—Address by, 37.—Discussion by, 42, 45, 50.—On Committee, 46.—Permanent Chairman of Convention, 37.
Edge, George W.—Death announced, and Committee to prepare Memoir, 1, 108.—Memoir, 18.

EGLESTON.

Egleston, T.—Discussion by, 94.
Elastic Limit in Metals, Variation due to Orthogonal Strains, by R. H. Thurston, 23.
Election of Officers, 90.
Emery, Charles E.—Discussion by, 48, 98.
Emmet, Thomas Addis.—Death announced, and Committee to prepare Memoir, 1, 8, 108.—Memoir, 2.
Ericsson, John.—Admitted as Honorary Member, 58, 62.
Errata, 126.

Field, George S.—Admitted as Member, 23, 31.
Finance Committee. (See Committee.)
Finances of Society, 108. (See Committee.) (See Treasurer.)
Fink, Albert.—On Committee, 50.—Presides at Meeting, 18.
Fiscal Year, Change proposed, 49.
Flad, Henry.—On Committee, 41, 46, 50.
Flow of Streams, by A. Fteley, 98.
Ford, Arthur L.—Death announced, and Committee to prepare Memoir, 56, 57, 108.—Memoir, 75.
Forney, M. N.—Discussion by, 48, 57.—On Committee, 57.
Fox, Stephenson Waters.—Admitted as Junior, 58, 68.
Francis, James B.—Censor to award Norman Medal, 69, 91, 108.—Discussion by, 42, 45.—Elected President, 90.—Presides at Convention, 37.—Presides at Meeting, 49.
Frazier, James L.—Admitted as Member, 69, 87.
Freeman, Claude.—On Committee, 46.
Fteley, A.—Paper by, 98.

Gates, C. L.—Paper by, 42.
Gauging of Streams, Report of Committee, 43, 77, 98.
Goodwin, J. M.—Discussion by, 2.
Graff, Frederick.—On Committee, 45.
Greene, B. H.—On Committee, 49.
Greene, G. S.—Discussion by, 85.
Greenwood, William H.—Admitted as Member, 18, 31.—Death announced, 82, 83, 108.

Hammond, Henry B.—Admitted as Associate, 58, 88.
Hardee, Thomas S.—Death announced and Committee to prepare Memoir, 49, 56, 108.

HARLOW.

Harlow, J. H.—Discussion by, 42.
Harrod, B. M.—Makes report, 44, On Committee, 49.
Haswell, Charles H.—Presides at Meeting, 69.
Hawkshaw, Sir John.—Admitted as Honorary Member, 124.
Hayes, E.—Discussion by, 113.
Hayward, James A.—Death announced, 69, 82, 108.
Hermany, Charles.—Censor to award Norman Medal, 69, 91, 108.
Heuer, William H.—Admitted as Member, 18, 31.
Hilgard, Julius E.—Discussion by, 98.—On Committee, 50.
Hjortsberg, Max.—Death announced and Committee to prepare Memoir, 49, 56, 108.
Holley, A. L.—On Committee, 9.
House of the Society. (See Announcements.)
Hudson River Tunnel, by Arthur Spielman and Charles B. Brush, 42.
Hughes, William M.—Admitted as Member, 50, 54.
Hutton, W. R.—Discussion by, 42, 50, 96.

Institute of Mining Engineers, 15.
Inter-Oceanic Canal Projects, 1, 2, 10, 17, 18, 23, 83, 85.

Jackson, Thomas.—Admitted as Member, 33.
Jetties, Notes on South Pass, by Max E. Schmidt, 45.
Johnson, Lorenzo M.—On Committee, 46.—Transferred Junior to Member, 23, 36.

Katte, Walter.—Discussion by, 96.—On Committee, 49.—Presides at Meeting, 9.
Kelley, F. M.—Discussion by, 2.
Kellogg, Charles.—Admitted as Member, 50, 54.
Kennedy, James C.—Resignation of, 111.
Kinsley, T. P.—Discussion by, 85, 113.
Knapp, George O.—Resignation of, 111.
Knight, William B.—Transferred Junior to Member, 1, 36.

Leach, Smith S.—Admitted as Member, 58, 82.
Lesseps, M. de.—Discussion by, 9, 10.

LIBRARY.

Library and Museum.—Additions to, 13, 26, 51, 65, 77, 85, 121.—Catalogue, 77, 105, 121.—Publications and Papers received for, 118.—Statement and Increase, 105.
Library Committee. (See Committee.)
Library, Consultation and Circulation of Books of the, 106.
Light, Relative Efficiency of Gas and Electric, by G. W. Dresser, 33.
Light-house in Pascagoula Harbor, Renewal of Foundation and Transfer of, by J. W. Putnam, 113.
List of Members—Additions to, 7, 16, 21, 31, 35, 54. 62, 68, 82, 87, 111, 124.
— Changes and Corrections, 8, 16, 21, 31, 36, 55, 62, 68, 82, 88, 111, 125.
— Deaths, 8, 16, 32, 56, 82, 108, 125.
— Resignations, 16, 82, 88, 112.
List of New Books on Engineering and Technology. (See Books.)
Locks, Ship Canal, Calculated for Operation by Steam, by Ashbel Welch, 45.
Long, Thomas J.—Transferred Junior to Member, 1, 7.

Macdonald, Charles.—Discussion by, 50, 57.—On Committee, 41, 50, 57.—Paper by, 18.—Resolution by, 49.
MacNaughton, James.—Admitted as Member, 33, 54.
Malezieux, Emile.—Admitted as Honorary Member, 124.
Manley, Herny.—Admitted as Member, 50, 54.
McMath, Robert E.—Admitted as Member, 18, 21.—On Committee, 46.—Paper by, 45.
McNulty, George, W.—Admitted as Member, 33, 82.
Meetings.—Annual. (See Annual.)
— General, 103, 104.
— Omitted in Summer Months, 58.
— Statement of, 103.
Meier, Edward D.—Admitted as Member, 9, 31.—On Committee, 46.
Members, Additions to. (See List.)—Ballots for. (See Ballots.)—Changes of Address. (See List.)—Deaths. (See List.)—Engagements for, 107.—Number of, 101.—Professional Record of, 10, 107.—Resignations of. (See List.)
Membership, Method of Balloting for, and Election to, 49, 58, 70.—Statement and Increase of, 101.

MEMOIRS.

Memoirs of Deceased Members, 2, 4, 18, 24, 75.—Thomas Addis Emmett, 2.—Warren Colburn, 4.—George W. Edge, 18.—A. W. Craven, 24.—Arthur L. Ford, 75.
Memphis, The Sewerage of, by F. S. Odell, 98.
Menocal, A. G.—Paper by, 83, 85.
Merrill, William E.—On Committee, 45.
Metals, Elastic Limit, Variation due to Orthogonal Strains by, R. H. Thurston, 23.
Metcalf, William.—Discussion by, 58, 73.
Metric System. (See Announcements).
Minutes of Meetings of Board of Direction, 10, 34, 58, 69, 100, 114.
— January, 7th, 1880, Proposals Considered, 10.
— January 19th, 1880, Proposals considered; action taken as to Committees on Tests of Cement and on Preservation of Timber; circular to be issued requesting biographical records of members; circular to be issued as to professional information to be furnished to members; financial business transacted, 10.
— February 5th, 1880, Proposals considered, 10.
— February 11th, 1880, Proposals considered; arrangements for special meeting made; appropriations made, 10.
— March 11th, 1880, Proposals considered; action taken as to Committees on Preservation of Timber and on Tests of Cements, 34.
— April 5th, 1880, Proposals considered; action taken as to lease of house; action taken as to members in arrears; programme for 12th Annual Convention considered, 34.
— April 7th, 1880, Proposals considered, 34.
— May 6th, 1880, Proposals considered; appropriations made; action taken as to members in arrears, 34.
— June 9th, 1880, Proposals considered; action taken as to members in arrears; appropriations made, 58.
— July 13th, 1880, Proposals considered, 58.

MINUTES.

— August 3d, 1880, Proposals considered; action taken as to arrears of dues; appropriations made; Board of Censors to award Norman medal appointed, 69.
— October 1st, 1880, Arrangements made for annual meeting; action taken on report of Nominating Committee; appropriations made, 100.
— November 1st, 1880, Proposals considered; Secretary's report received and annual report perfected, 100.
— November 10th, 1880, Board organized; Standing Committees appointed; proposals considered; appropriations made, 100.
— December 8th, 1880, proposals considered; provision for permanent quarters discussed, 114.
— December 22d, 1880, Mode of issuing ballots determined; action taken as to proposed fund for permanent quarters, 114.
— December 29th, 1880, Proposals considered; action taken as to fund for permanent quarters; resolutions adopted, and form of circular determined, 114.
Minutes of meetings of the Society, 1, 2, 9, 10, 17, 18, 23, 33, 48, 57, 69, 83, 89, 113.
— January 7th, 1880, Ballot for membership canvassed; ballot for place of Twelfth Annual Convention canvassed; St. Louis adopted; discussion on Inter-oceanic Canal projects, continued, 1.
— January 14, 1880, Deaths of George W. Edge, and T. A. Emmett announced; discussion on Inter-oceanic Canal projects continued, 1.
— January 21st, 1880, Discussion on Inter-oceanic Canal projects continued, 2.
— February 4th, 1880, Death of John C. Thompson announced; committee appointed to arrange for address by M. de Lesseps; ballots for membership canvassed; ballots for amendments to Constitution canvassed—one adopted, one not adopted; report of Committee on Quarters presented 9.
— February 26th, 1880, Meeting at Theatre of Union League Club; discussion on Inter-oceanic Canal projects by M. de Lesseps and others, 10.
— March 3d, 1880, Discussion on Inter-oceanic Canal projects continued; ballots for membership canvassed, 17.
— March 17th, 1880, Discussion on Inter-oceanic Canal projects, continued, 18.
— April 7th, 1880, Ballots for membership canvassed; discussion on Inter-oceanic Canal projects continued; "Variation due to orthogonal strains in the elastic limit of metals" by R. H. Thurston, read and discussed, 23.
— April 21st, 1880, Death of I. M. St. John announced; arrangements for Convention; notes on experiments on the relative efficiency of gas and the electric light by George W. Dresser, read and discussed, 33.
— May 5th, 1880, Ballots for membership canvassed; rooms to be hereafter open on evenings of Wednesday instead of Thursday of each week, 33.
— May 19th, 1880, "Suggestions and notes in regard to a new decimal system of weights and measures," by T. S. Sedgwick, read and discussed, 48.
— May 26th, 1880, Business meeting at Convention; suggestions for change of date of annual meeting and close of fiscal year discussed; deaths of Thomas S. Hardee and of Max Hjortsberg announced, and committees to prepare memoirs appointed; rules for nomination and election to membership discussed; resolution in reference to employment of Civil Engineers upon public works offered, discussed, amended, adopted and committee appointed, 49; places for 13th Annual Convention suggested, 50.
—June 2d, 1880, Ballots for membership canvassed, 50.
—June 16th, 1880, Death of Arthur L. Ford announced and committee appointed to prepare memoir; "Cheap Transportation versus Rapid Transit and Delivery," by M. Coryell read and discussed, 57.
—July 7th, 1880, Rules for nomination

and election to membership discussed, 57; election of JOHN ERICSSON, JUSTIN DIRKS and BARON VON WEBER as honorary members announced; ballots for membership canvassed, 58.

—September 1, 1880, Death of JAMES A. HAYWARD announced: "Harbor Improvements of Quebec" by J. VINCENT BROWNE read; "The Strength of Wrought Iron Columns" by G. BOUSCAREN read; committee on employment of civil engineers on government work asked extension of time; ballots for membership canvassed, 69.

—September 15th, 1880, Death of WILLIAM H. GREENWOOD announced; discussion on inter-oceanic canals continued, 83.

—October 6th, 1880, Ballots for membership canvassed; arrangements for annual meeting made, 83; proposed amendment to Constitution submitted, 84; letter in reference to report of United States Board to test metals read; Inter-oceanic canal discussion continued, 85.

—October 20, 1880, Wind pressure discussed, 89.

—November 3d, 17th, 18th, 1880, Annual Meeting (see minutes of,) 89.

— December 1st, 1880, Ballots for membership canvassed; "Renewal of Foundation and Transfer of Lighthouse in Pascagoula Harbor" by J. W. PUTNAM read and discussed, 113.

—December 15th, 1880, "Wind Strains in Bridges" by C. SHALER SMITH read; description of arch centering presented, 113.

Minutes of Twelfth Annual Convention, 37; St. Louis, May 25th, 1880; called to order by JOHN BOGART, Secretary; chair taken by Vice-President JAMES B. FRANCIS; JAMES B. EADS elected Chairman of Convention; WILLIAM P. SHINN, Vice-Chairman; Address by JAMES B. EADS, 37.—Address by Hon. HENRY OVERSTOLZ, Mayor of St. Louis, 38. —List of members and guests, 40; Committee on arrangement of papers and discussions, 41; Programme of excursions and local invitations; "The Hudson River Tunnel" by ARTHUR SPIELMAN and CHARLES B. BRUSH read and discussed; "Location of the Chimbote Tunnels" by O. F. NICHOLS read, 42; Second Session, 9 A.M., May 26th; "Tensile Tests of Cements, and Appliances for more Accurate Determinations" by D. J. WHITTEMORE read and discussed; "American Cements" by F. O. NORTON read and discussed; "Waterproof Coverings" by F. COLLINGWOOD read; "Web Strains in Simple Trusses" by E. SWEET, JR., read; "The Crippling Strength of Wrought Iron Columns" by C. L. GATES read; report for Committee on Tests of Iron and Steel referred to and discussed, 42; Report of Committee on Gauging of Streams; Report of Committee on Tests of Cements; Committees continued; Report of Finance Committee, 43; Report of Committee on Preservation of Timber, 44; Nominating committee appointed, 45; Third Session, 8 P. M. May 26th; Annual address read; Business meeting held (see minutes), 45; Fourth Session, 9 A. M., May 28th; "Ship Canal Locks Calculated for Operation by Steam" by ASHBEL WELCH read; "Practical Consequences of the Variation of the Wet Section of Rivers" by R. E. McMATH read; "Notes on the South Pass Jetties" by MAX E. SCHMIDT read and discussed; "Cheap Transportation versus Rapid Transit and Delivery" by M. CORYELL presented; "Wind Pressure against Bridges" by ASHBEL WELCH read and discussed; Committee as to Wind Pressures appointed; "Improvement of the Harbor of Quebec" by J. VINCENT BROWNE presented; resolution of thanks, 45; Convention adjourned; Arrangements by, and members of Local Committee; General programme for each day; Excursions and visits to various localities, 46.

Minutes of Twenty-eighth Annual Meeting, November 3d, 1880; Annual report of Board of Direction presented, ordered printed and submitted at adjourned meeting; Tellers for ballot appointed; Annual reports of Treasurer and Finance

Committee presented; Report of Committee on Uniform System of Tests of Cement presented; Amendment to Constitution considered, 89; Suggestions for place of Thirteenth Annual Convention presented; recess taken to 8 P. M.; ballots for membership canvassed; ballots for officers canvassed and result announced; adjourned to November 17th, 90.

—November 17th, 1880. Arrangements for meeting announced; Annual report of Board of Direction accepted; Reports of Treasurer and Finance Committee accepted; Committee on Tests of Cement continued; Report of Board of Censors to award Norman Medal presented; Medal awarded to THEODORE COOPER, 90; Suggestions for place of Thirteenth Annual Convention presented, discussed and letter ballot ordered to determine place, 91; Proposed amendments to Constitution discussed, 93; 8.30 P. M., proposed amendments to Constitution discussed and amended; Amendment to By-Laws proposed, 97; ordered issued with arguments for and against; Report of Committee on Gauging Streams presented and discussed; Paper on flow of streams by A. FTELEY read and discussed; "The Sewerage of Memphis" by F. S. ODELL read and discussed; Adjournment of meeting; Programme of excursions and entertainments connected with Annual Meeting, 98; Attendance at Annual Meeting, 100.

MITCHELL, HENRY.—Admitted as Member, 1.

MORISON, GEORGE S.—Discussion by, 113.—Plattsmouth Bridge, 48.

MOORE, CHARLES E.—Admitted as Member, 1, 16.

MOORE, ROBERT.—Discussiou by, 50.—On Committee, 46.

MORSE, HENRY G.—Admitted as Member, 23, 54.

NEILSON, CHARLES.—Admitted as Member, 1, 31.

New Books on Engineering and Technology. (See Books.)

NEWTON, ISAAC.—Admitted as Member, 18, 21.

NICHOLS, AURIN B.—Admitted as Member, 1.

NICHOLS, O. F.—Paper by, 42.

Norman Medal, Award, 90.—Board of Censors to award, 69, 90.—Code of Rules for its Award, 60, 64, 81.

NORTH, E. P.—Appointed Teller, 89.—Discussion by, 2, 57, 58.

NORTON, F. O.—Paper by, 42.

NOYES, ELLIS B.—Admitted as Junior, 58, 68.

OCKERSON, JOHN A.—Admitted as Member, 58, 68.

ODELL, F. S.—Paper by, 98.

OVERSTOLZ, HENRY.—Address at Convention, 38.

PAINE, WILLIAM H.—Elected Director, 90.—Makes Report, 43, 109.—On Committee, 100.—Presides at Meeting 89, 90.

PALMER, FRANCIS INGRAM.—Admitted as Member, 113, 125.

PEGRAM, GEORGE H.—Admitted as Junior, 23, 36.

Permanent Quarters for the Society, Action Taken, 114 —Committee on, 10, 106.

PHILBRICK, E. S.—Discussion by, 98.

Plattsmouth, Excursion to and Bridge at, 48.

POPE, WILLARD S.—On Committee, 49.

Preservation of Timber. (See Timber.)

PRINDLE, F. C.—Discussion by, 18.

Professional Information through Secretary, 10, 106.

Publications and Papers received for Library, 118.

PUTNAM, JOSEPH W.—Admitted as Associate, 18, 31.—Paper by, 113.

Quebec, The Improvements of the Harbor of, by J. V. BROWNE, 45, 69.

RADENHURST, WILLIAM N.—Transferred Junior to Member, 58.

Records of Members, 10, 107.

Report, of Board of Direction, Annual, 89, 90, 100, 101.—Appendix to, 118.

— Of Treasurer, 89, 90, 116.

Reports of Committees. (See Committees.)

REPORTS.

Reports made, List of, 104.
Resignation of Members. (See List.)
Reuschel, William.—Admitted as Junior, 50, 68.
Richards, Joseph R.—Admitted as Associate, 7, 9.
Richardson, Henry B.—On Committee, 49.
Rivers, Practical Consequences of Variation of the Wet Section of, by Robert E. McMath, 45.
Robinson, Albert A.—Admitted as Member, 33, 54.
Rockwell, Samuel.—Admitted as Member, 1.
Ross, William B.—Resignation of, 88.

Schmidt, Max E.—Discussion by, 42. —Paper by, 45.
Sedgwick, T. S.—Paper by, 48.
Sewerage of Memphis, by F. S. Odell, 98.
Seymour, Horatio, Jr.—Transferred Associate to Member, 23, 36.
Shailer, Robert A.—Admitted as Member, 18, 36.
Shelbourne, S. F.—Discussion by, 83.
Shickle, F.—On Committee, 46.
Shinn, W. P.—Discussion by, 42, 43, 49, 70, 94.—On Committee, 46.—Vice-Chairman of Convention, 37.
Simpson, George Hume.—Admitted as Member, 83, 111.
Slataper, F.—Discussion by, 94.
Smedley, S. L.—Discussion by, 98.
Smith, Charles A.—Admitted as Member, 23, 55.
Smith, C. Shaler.—Discussion by, 45, 49, 50, 72.—On Committee, 45, 46. —Paper by, 113.
Smith, C. Vandervoort.—Elected Director, 90.—On Committee, 100.
South Pass Jetties. (See Jetties.)
Spielmann, Arthur.—Paper by, 42.
Stanton, Robert B.—Admitted as Member, 69, 88.
Steam Engines, Discussion on Cushioning the Reciprocating Parts of, by Charles E. Emery and J. W. Hill, 111, 115.
St. John, Isaac Monroe.—Death announced, and Committee to prepare Memoir, 32, 33, 108.
St. Louis, Bridge at, 48.—Convention at, 1, 7, 15, 33, 34, 37.—Engineers Club of, 45.
Strains, Variation due to Orthogonal Strains in the Elastic Limit of Metals, by R. H. Thurston, 23.
— Web Strains in Simple Trusses, by E. Sweet, Jr., 42.
Strang, S. A.—Discussion by, 57.
Sweet, Charles A.—Admitted as Member, 18, 21.
Sweet, E. Jr.—Paper by, 42.

Tests of Cement. (See Cement.)
Tests of Iron, Steel and Other Metals, Committee on. (See Committee.) United States Board for, 85.
Thompson, John C.—Death announced, and Committee to prepare Memoir, 9, 16, 108.
Thurston, R. H.—Communication from, 85.—Paper by, 23.
Timber, Committee on Preservation of. (See Committee.)
Tintorer, Jose Gibergа.—Admitted as Member, 33, 55.
Transactions, 108.
Transportation, Cheap, versus Rapid Transit and Delivery, by M. Coryell, 45, 57.
Treasurer, Annual Report, 89, 90, 116.
Trusses, Web-Strains in Simple, by E. Sweet, Jr., 42.
Tunnel, Chimbote, Location of, by O. F. Nichols, 42.
— Hudson River, The, by Arthur Spielmann and C. B. Brush, 42.

Van Auken, D. H.—Description of Centering, by, 113.
Van Brocklin, Martin.—Admitted as Member, 1, 21.
Vance, Hart.—Admitted as Member, 58, 88.
Vanderpool, E.—On Committee, 2, 18.
Van Horne, John G.—Admitted as Member, 7, 9.—Appointed Teller, 89.

Waite, Christopher C.—Admitted as Member, 18, 31.
Walker, William Williams.—Admitted as Member, 83, 111.
Ward, Charles D.—Discussion by, 2.
Ward, L. B.—Discussion by, 85.
Waterproof Coverings, by F. Collingwood, 42.
Weber, Max Maria, Baron Von.—Admitted as Honorary Member, 54, 58.—Discussion by, 57.
Weights and Measures, Suggestions and Notes in regard to a new

WEIR.

Decimal System of, by T. S. Sedgwick, 48.

Weir, Charles G.—Admitted as Member, 33, 55.

Welch, Ashbel.—Discussion by, 2, 10, 17, 18, 42, 58, 83, 98, 113.—Elected Vice-President, 90.—On Committee, 100.—Paper by, 45.—Presides at Meeting, 57, 96, 113, 114.

Wellman, D. W.—On Committee, 46.

Wheaton, Edward.—Admitted as Associate, 9, 16.

Whitelaw, John.—Discussion by, 50.

Whitman, T. J.—On Committee, 46.

Whittemore, D. J.—Discussion by, 42.—Elected Director, 90.—Paper by, 42.—Report by, 43, 110.

WIND.

Wind Pressure, Against Bridges, by Ashbel Welch, 45.
— Discussion of, 89.

Wind Strains in Bridges, by C. Shaler Smith, 113.

Worthen, W. E.—Discussion by, 98, 113.—Presides at Meeting, 113.

Worthington, Henry R.—Death announced, 125.

Wright, Horatio G.—Admitted as Honorary Member, 16, 18.

Wyse, L. N. B.—Discussion by, 23.

Yardley, Edmund.—Discussion by, 48, 58.

Yonge, Samuel H.—Admitted as Member, 33, 55.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VI.—January, 1880.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

JANUARY 7TH, 1880.—The Society met at 8 P. M., Vice-President Chanute in the chair. Ballots for admission to membership were canvassed, and the following were declared elected Members: William B. Knight (elected Junior January 6, 1875), Kansas City, Mo.; Thomas J. Long (elected Junior November 3, 1875), New York City; Henry Mitchell, U. S. Coast Survey; Charles E. Moore, Fayetteville, Vt.; Charles Neilson, New York; Aurin B. Nichols, Washington, D. C.; Samuel Rockwell, Brooklyn, N. Y.; Martin Van Brocklin, New York.

The ballots for determining the place of the Twelfth Annual Convention were canvassed, with the following result:

For St. Louis	64 votes.
" San Francisco	45 "
" Washington	40 "

Whereupon it was determined that the Convention should be held at St. Louis.

A paper in continuation of the discussion on Inter-Oceanic Canal Projects was then read by Julius W. Adams, Past President of the Society.

JANUARY 14TH, 1880.—The Society met at 8 P. M., George W. Dresser in the chair. The deaths on January 1st, 1880, of George W. Edge, Member of the Society, and on January 12th, 1880, of Thomas Addis Emmet, Member and one of the Founders of the Society, were announced, and Committees to prepare memoirs for publication were appointed, as follows: To prepare a memoir of George W. Edge,

Messrs. Armington, Vanderpool and the Secretary ; to prepare a memoir of Thomas A. Emmet, Messrs. Julius W. Adams, P. P. Dickinson and the Secretary.

The discussion upon the subject of Inter-Oceanic Canal Projects was continued by Ashbel Welch, Charles D. Ward and F. M. Kelley, and by a paper by John C. Campbell, presented through the Secretary.

JANUARY 21ST, 1880.—The Society met at 8 P. M., Vice-President Chanute in the chair. The discussion upon the subject of Inter-Oceanic Canal Projects was continued by E. P. North, T. Cooper, J. M. Goodwin (through the Secretary) and O. Chanute.

MEMOIRS OF DECEASED MEMBERS.

THOMAS ADDIS EMMET,* Member A. S. C. E.

DIED JANUARY 12TH, 1880.

Thomas Addis Emmet was born in the city of New York, June 4th, 1818, the son of Robert Emmet, and grandson of Thomas Addis Emmet.

He was educated principally at the school of the Rev. William Powell, and was there prepared for Columbia College, which he entered in the year 1834. He remained at college only one year, his inclination being for a more active life. In 1835 or 1836, having decided on the profession of Civil Engineer, he was appointed to a position on the first surveys that were made by the Erie Railroad at Deposit, Delaware County, New York. He was afterwards transferred, in the same employment, to Tappan, New York, where he remained until 1840. He then took a position with Major McNeil in the construction of a railroad in South Carolina, between Columbia and Charleston, and remained there one year, when he returned to New York and was appointed to the State Survey of the head waters of the Hudson River, where he continued until they were completed.

Between 1843 and 1851 he was engaged upon the construction of the Erie and Hudson River Railroads. His next employment was in Pennsylvania, on some of the coal roads, and he was the Chief Engineer of the Cattawissa Railroad, which was completed under his charge. He was next in charge of a division of the Erie Railroad, and after its completion retired for a period from the profession, and was elected the President of an insurance company in the city of New York. After two years' experience of an inactive life in the City, he resigned this position and returned to his profession, which he found more congenial to his tastes and habits. From that time he was principally employed on the Erie Railroad. He

* Committee to prepare memoir, Julius W. Adams P. P. Dickinson, John Bogart.

had charge of the construction of the line from Paterson to Hoboken, and also of the Niagara River branch, and was for several years on the Delaware Division, where twenty years before he had commenced his professional career.

After leaving the Erie Railroad he was appointed an assistant in the Croton Aqueduct Department. This was about the year 1870. He from that time resided at Carmel, in Putnam County, New York, and was in charge of the reservoir, and various sources of water supply in that section. He superintended the construction of the large reservoir lately completed at Brewsters, in Putnam County, and various other works connected with it. Latterly he had been principally employed nearer the city on examinations for further water supply, and on surveys for a new aqueduct, but he still retained his superintendence of the Putnam County works, and was there engaged with his duties at the time of his death.

Up to a very recent period he had enjoyed very robust health, promoted, no doubt, by his active out-of-door life. On January 1st he had an alarming attack of difficulty of respiration, but he had apparently entirely recovered from it, and actively continued in the discharge of his duties. On the 12th of January he went to Carmel, seemingly well, intending to return on the following day. He was occupied all day. After he had retired for the night he was attacked with the same symptoms of difficulty of breathing. He had prompt assistance, which was of no avail. He died in twenty minutes after he was attacked, having retained his consciousness to within a few minutes of his death.

His professional life covered a period of nearly forty-five years. He loved and took pride in its practice, and highly prized the intimacies and friendships he contracted in the course of it. He filled his various positions conscientiously, justly and honestly. It was not in his nature to do otherwise. He was unassuming and unobtrusive ; free from false pretense; unselfish and generous; rigidly upright and just in all his dealings; manly and courageous in all his thought and actions, and his friendships were sincere, lasting, and to be depended on.

He never married, and through boyhood and manhood his ties to his kin were of the tenderest character. With them he passed all his leisure time, and found among them his recreation and happiness.

Mr. Emmet was one of the twelve who, on November 5th, 1852, met at the Croton Aqueduct Department in the City of New York and founded this Society. His membership has continued without interruption since that date. During the twenty-seven years of the existence of the Society his interest in it has always been sustained. Very few of the men to whom the Society owes its origin are left with us, and this loss of one of them prompts the reflection that they laid its foundation well and skillfully. Essentially the same to-day in its objects, its aims and its laws, with such changes only as have been made necessary by its growth and enlarged

area of membership, the Society may well make record of the proven wisdom and forethought of its early members, and acknowledge the debt it owes to the founders of the American Society of Civil Engineers.

WARREN COLBURN,* Member A. S. C. E.

DIED SEPTEMBER 15TH, 1879.

Warren Colburn (elected member of the Society March 18th, 1868), was born in the Town of Waltham, Massachusetts, on the 18th day of August, 1824. He was the eldest son of Warren Colburn, the famous mathematician and author of a series of arithmetics and other more advanced mathematical works. At an early age he was sent to the public schools in the City of Lowell, where he evinced an unusual aptitude for learning, particularly in mathematics, his apprehension of that science seeming almost preternatural. At the age of thirteen he entered the celebrated preparatory school of the late Dr. Muhlenberg, at Flushing, Long Island, where he pursued his studies assiduously for a series of years and received an admirable intellectual training, making for himself an excellent record for scholarship. While at this school he attained such proficiency in mathematics that it appears to have been the pastime of his leisure hours to compose mathematical problems, many of which were so highly esteemed for their originality that a leading scientific journal published them as productions of an intellect of rare mathematical promise.

Mr. Colburn's first business employment after leaving school was in the capacity of an actuary of an insurance company, engaged more particularly in the preparation of insurance computations and mathematically tabulated scales. But the impulse of his mind towards Civil Engineering was so predominant that he soon relinquished this position for a subordinate one in an engineering party on the Fitchburg Railway. With his superior mathematical attainments, ready apprehension and natural genius for Civil Engineering, he soon acquired a practical mastery of the rudimentary principles of that profession. Upon concluding his engagement with that line, he was appointed Assistant Engineer of the Cheshire Railway, the duties of which office he most efficiently and satisfactorily discharged up to the period of the completion of that work, in the year 1849.

Mr. Colburn was then, and when he had barely attained his twenty-fifth year, appointed Chief Engineer of the Ashuelot Railway, certainly a flattering testimonial to his professional proficiency and enterprise. He remained in the personal supervision of the engineering of this road

* Committee to prepare memoir, John Bogart, Secretary. The Secretary desires to acknowledge the kindness of John N. Drummond, Esq., of Toledo, O., who, though not a member of this Society, has with great care collected the materials for this memoir.

until it was finished and ready for operating, and the solidity and thoroughness of its construction well attests the skill and sound engineering judgment exercised in its prosecution.

At the beginning of the year 1851 Mr. Colburn was appointed Chief Engineer of the Rochester, Lockport & Niagara Falls Railway, including the Lockport & Buffalo Railway. His supervision of the construction of these roads continued until both were finished, and his management of all departments of the work was characterized by marked energy, skill, tact and business ability. Upon the opening of these roads for traffic he was appointed General Manager, and performed the duties of that office until both were merged by consolidation into the New York Central Railway.

In the year 1853 Mr. Colburn was elected to the office of Chief Engineer of the Lake Erie, Wabash & St. Louis Railway (commonly known as the Wabash Line). He entered upon the duties of the surveying, locating and construction of this extended line of railway during the month of May of that year, and accomplished its completion late in the autumn of 1856. The difficulties attending the building of this great road, with its extensive bridging and other formidable and expensive artificial structures, as well as those arising from sharp conflicting interests as to its location, he met and most successfully surmounted, his ripe professional experience and discreet judgment seeming all-sufficient for the solution of every problem, the reconciling of all differences, and the encompassing of the wisest and most judicious results. On the opening of this line he was appointed Vice-President and General Manager, and during the eleven ensuing years he continued to fill those positions in a manner acceptable to the company and with the confidence and esteem of all with whom he had business intercourse.

After his withdrawal from the last-named line Mr. Colburn was made Chief Engineer of the Decatur & East St. Louis Railway. He supervised the surveys, location, construction and equipment of this railway, and that having been accomplished, he delivered it over to the Wabash Line, which absorbed it by consolidation.

Mr. Colburn was also elected President of the La Fayette, Bloomington & Mississippi Railway, and supervised its engineering and construction until it was completed, when it became leased to the Wabash Line.

At this juncture Mr. Colburn, after a long and arduous professional experience extending over a period of nearly thirty years, permanently withdraw from all direct personal participation in railway construction and management—thus concluding a career of public official life that was eminently useful and successful, distinguished for a thoroughly scientific and practical mastery of his profession, and inflexible adherence to the highest principles of manly firmness and honor.

In the year 1871 Mr. Colburn visited Europe, and prolonged his sojourn there through a period of more than two years. Soon after his

return he accepted a temporary position as Commissioner for the joint Trunk Lines, but his connection with railway affairs thereafter was almost exclusively of an advisory and consulting character, a service to which he, of course, brought the advantages of ripe professional skill and thoroughly matured practical experience. During the later years of his life, he was often selected by the courts to act as a commissioner and arbitrator in controversies between railway companies involving questions of construction and engineering, and it has been particularly noticeable that his conclusions in such cases have been so clear, accurate, impartial and convincing, that they have been accepted by contestants and made the judgment of the court.

Thus far reference has been made almost exclusively to those points of Mr. Colburn's character, which were more directly open to public and general observation. Before concluding, it seems but proper that some brief expression should be given to the feelings with which his memory was cherished by his associates and those who were favored by his friendship.

In intellectual power and quality Mr. Colburn was not only an uncommon man, but an uncommon style of a man. He was an original thinker, an extensive reader, gifted with a prodigious memory, and an acute faculty for discrimination and analysis. His power of abstraction and concentration of thought was such, that the processes of his mind towards results seem to have had the quickness of intuition. His knowledge of his profession unquestionably was extensive, practical and profound, the result, no doubt, of a well-directed early training and assiduous study and reflection. It was due to this fact that in questions of Civil Engineering his opinions were so generally esteemed and accepted as of the highest authority.

Mr. Colburn was a man of genuine integrity and disinterestedness of character, free from ambition, and without a trace of an unworthy aim or an ungenerous purpose. He never sought praise or preferment, but rather recoiled from everything calculated to bring him into prominence or secure personal influence or reward. While he was firm in his own convictions, he was generously tolerant towards those of others. Although somewhat predisposed to be reserved and reticent in manner, he was in reality genial and courteous, approachable and sympathetic.

In person Mr. Colburn was healthful and vigorous to an unusual degree — tall, broad-shouldered, muscular, and of imposing presence — with finely-cut features, a keen, clear, bright eye, and a face full of youthful animation, intelligence and intensity of purpose. During the past twenty or more years he had made his permanent home at Toledo, Ohio. He died at Saratoga Springs on the 15th day of September last, in the mellow ripeness of a well-rounded life, and the tender appreciation of a wide circle of loving friends will cherish and preserve his memory.

ANNOUNCEMENTS.

The Twelfth Annual Convention of the Society will be held at St. Louis. The time will be the latter part of May. The particular date will soon be announced,

The following resolutions were adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications :

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of the differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door east from Fourth avenue, and near the southwest corner of Gramercy Park. It is open from nine o'clok A.M., to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P.M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P.M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings, both for consultation of books and periodicals and for conversation.

* * *

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
LONG, THOMAS J.	(Elected Junior, Jan. 6, 1875), Assistant Engineer, Department of Docks, 26 West 60th St., New York City, N. Y.	January 7, 1880.
VAN HORNE, JOHN G.	Assistant Engineer, Metropolitan Elevated Railroad, 437 Communipaw Ave., Jersey City, N. J.	February 4, 1880.

ASSOCIATE.

RICHARDS, JOSEPH R.	46 Court St., Boston, Mass.	February 4, 1880.

CHANGES AND CORRECTIONS.

CONSTABLE, CASIMIR.....Constableville, Lewis Co., N. Y.
PEARSONS, GALEN W.....Oceanus P. O. (Rockaway Beach), Queens Co., N. Y.
SEARS, ALFRED F.....Portland, Oregon.

JUNIOR.

LUCAS, D. JONES.....233 South 4th St., Philadelphia, Pa.

DEATH.

EMMET THOMAS ADDIS ....Elected Member November 5, 1852. Died January 12, 1880.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VI.—February, 1880.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

FEBRUARY 4TH, 1880.—The Society met at 8 P. M., Mr. Walter Katté in the chair.

The death of John C. Thompson, Member of the Society was announced, and A. L. Holley and John Bogart were appointed a committee to prepare a memoir for publication.

The approaching visit to New York of M. de Lesseps, and the engineers accompanying him, was announced, and a committee was appointed to make arrangements for a proper reception of these gentlemen, and for their participation in discussion at a meeting of the Society.

Ballots for admission to membership were canvassed, and the following were declared elected: As Members, Henry D. Blunden (elected Junior January 5, 1876), of New York, Andrew J. Chaphe, of St. Louis, Mo., Edward D. Meier, of St. Louis, Mo., John G. Van Horne, of Jersey City, N. J.; as Associates, Joseph R. Richards, of Boston, Mass., Edward Wheaton, of Providence, R. I.

Ballots on proposed amendments to the Constitution were canvassed, with the following result:

On proposed amendment to Article XXII:

At the end of Article XXII, insert: On and after the fifth day of November, 1879, Past Presidents of the Society shall be Life Members, entitled to all the privileges of members without the payment of Dues.

There were..... 92 ayes.
" " ..... 53 noes.

This proposed amendment not having received an affirmative vote of two-third of all ballots cast was declared lost.

On proposed amendment to Article XXXIII:

To amend Article XXXIII. so that the amended article shall read as follows:

ARTICLE XXXIII.—Proposed amendments to this Constitution must be submitted in writing, signed by not less than five Members, on or before the first Wednesday in October, and then sent by letter to the several Members of the Society, at least twenty-five days previous to the Annual Meeting. Such amendments shall be in order for discussion *and amendment* at such Annual Meeting, and *with such amendments thereto as may have been approved by a majority vote of the Annual Meeting,* shall be voted upon by letter ballot, the vote to be counted at the first regular meeting in February. An affirmative vote of two-thirds of all ballots cast shall be necessary to secure the adoption of any amendment.

(The words in italics constitute the amendment; otherwise the Article is unaltered.)

There were ..... 128 ayes.
" " ..... 17 noes.

This amendment having received an affirmative vote of two-thirds of all ballots cast was declared adopted.

A report was presented from the Committee on Permanent Quarters. The report was received, the committee discharged, and the subject referred to a committee consisting of the President, Secretary and Standing Committee on Finance.

FEBRUARY 26TH, 1880.—The Society met at 7½ P. M., at the Theatre of the Union League Club in New York, Vice-President Chanute in the chair.

M. Ferdinand de Lesseps spoke, in French, in continuation of the discussion upon "Inter-Oceanic Canal Projects." His remarks were translated by Mr. N. Appleton. Mr. J. Dirks, C. E., of Amsterdam, Holland, followed, discussing engineering questions connected with the proposed construction of a canal at the Isthmus of Panama. Mr. V. Dauzats, C. E., of France, gave details of the depth of cutting at various points on the line at sea level, the lengths of the different excavations, the depth of soil, etc. The discussion was continued by Messrs. O. Chanute, Horatio Allen, Ashbel Welch, Cyrus Butler, J. Dirks, V. Dauzats and F. de Lesseps.

OF THE BOARD OF DIRECTION.

JANUARY 7TH, 1880.—Applications were considered.

JANUARY 19TH, 1880.—Applications were considered. The Secretary was directed to correspond with members of the Society in reference to their serving upon the Committees on Tests of Cements and on Preservation of Timber. The issue of a circular was directed requesting members to furnish biographical records. The issue of a circular as to professional information to be furnished to members was authorized. Financial business was transacted.

FEBRUARY 5TH, 1880.—Applications were considered.

FEBRUARY 11TH, 1880.—Action was taken as to a meeting to be held at the Theatre of the Union League Club. Applications were considered. Appropriations were passed.

LIST OF NEW BOOKS ON

ENGINEERNG AND TECHNOLOGY.

Alloys ; Copper-Tin Alloys. Report on a Preliminary Investigation of the Properties of Copper-Tin Alloys, made under the direction of the Committee on Metallic Alloys ; U. S. Board to test Iron, Steel and other Metals : Robert H. Thurston, Chairman. Washington. *Government Printing Office.* 1879. $2.50.

Army ; Guide for Regimental Courts Martial. Horatio C. King. 24mo. New York. *Van Nostrand.* $0.75.

—— The Russian Army and its Campaigns in Turkey in 1877–78. Lieut. F. V. Greene, U. S. A. 8vo. Atlas. New York. *Appletons.* $6.00.

Artisan's Year Book, and Engineer and Building Trades Almanack. 1880. Post 8vo. London. *Heywood*

Baggage Car Traffic ; illustrating Customs and Necessary Rules and Regulations of the Baggage Department and Parcel Traffic in the U. S. and Europe. Marshall M. Kirkman. New York. 12mo. *Railroad Gazette.* $2.00.

Bridges ; Handy Book for the Calculation of Strains in Girders and similar Structures. 3d Ed. Wm. A. Humber. London. 8vo. *Crosby Lockwood.* 7s. 6d.

—— Iron Bridges and Roofs, Elementary Theory and Calculations. August Ritter, Ph. D. Trans. from the German. 3d Ed. By H. R Sankey. 102 engs. 8vo, 395 pp. *E. & F. N. Spon.* $6.00.

—— Trusses and Arches by Graphical Methods. Part III. Arches in Wood, Iron and Stone, for Roofs, Bridges and Wall Openings; Arched Ribs and Braced Arches; Stresses from Wind and Changes of Temperature ; Stiffened Suspension Bridges. Charles E. Greene, A. M., Professor of Civil Engineering in University of Michigan. 1 Vol., 8vo. New York. *Wiley.* $2.50.

Catalogue of Scientific Serials of all Countries, incl. Transactions of Learned Societies in the Natural, Physical and Mathematical Sciences, 1633–1876. (Library of Harvard Univ., special publications,1.) 8vo. (Applied Sciences not included.) S. H. Scudder. *Cambridge Library.* $4.00.

Cables ; Experiments on the Strength of Wrought Iron and of Chain Cables ; Report of the Committees of the United States Board appointed to test Iron, Steel and other Metals, on Chain Cables. Malleable Iron, Reheating and Rerolling Wrought Iron ; including Miscellaneous Investigations into the Physical and Chemical Properties of Rolled Wrought Iron. By Commander L. A. Beardslee, U. S.N., Member of the Board and Chairman of the Committees, Revised and abridged by William Kent, M. E., formerly Assistant to the Committee on Alloys of the United States Board. With Heliotype Plate, showing Fractures. 8vo. New York. *Wiley.* $2.00.

Catskill Mountains, Map of. New York. *Scribners.* $0.75.

Civil Service in Great Britain. A History of Abuses and Reforms, and their Bearing upon American Politics. By Dorman B. Eaton. 8vo. New York. *Harpers.* $2.50.

College Fraternities ; a Descriptive Analysis of the Society System in the Colleges of the United States, with a detailed account of each Fraternity. William Raymond Baird. 12mo. Philadelphia. *Lippincott.* $1.50.

Concrete ; Practical Treatise on Natural and Artificial Concrete. Henry Reid. New ed., illus. 8vo. *E. & F. N. Spons.* $6.00.

Decimal System. A Manual for the use of Jewellers, Pawnbrokers Silversmiths, &c., with Examples of Decimal Calculations, Table of Value of Gold ; a Nomenclature for the New Troy Bullion Weights, and the Application to the System of Diamond Weights, with Tables of any Weights of Diamonds, from 0001 oz. to 10 ozs., and £1 to £10 a carat. W. J. Abbott. London. 12mo. *Maxwell.* 3s. 6d.

Dictionary of Engineering. Supplement to Spons. Division 1. (To be completed in three Divisions.) Ed. by Ernest Spon. Roy. 8vo, illus. *Spons, New York.* (Subscription.) $5.00.

Electricity and Magnetism, a Physical Treatise on. J. E. H. Gordon. London. Illus. *Low, Marston & Co.* (Announcement.)

Electricity as a Motive Power. W. E. Ayrtoun Sheffield. *Spons*

Electric Signals. With an Explanation of the Principles on which they are Constructed, and full Instructions for their Fixing and Maintenance. Edward Patterson. London. 8vo. *Spons.* 6d.

Electric Transmission of Power ; its present Position and Advantages. Paget Higgs, Cr. 8vo. New York. *E. & F. N. Spon.* $1.20.

Electrical Researches of the Hon. Henry Cavendish, F. R. S. Written between 1771 and 1781. Edited from the Original Manuscripts in the possession of the Duke of Devonshire, K. G., by J. Clerk Maxwell, F. R. S. Demy 8vo, cloth, with numerous Diagrams. *Cambridge University Press.* 18s.

Field Book for Engineers, Miners, Surveyors and Contractors. W. Davis Haskoll. 4th Ed., enl. illus. London. *Lockwood.* (Announcement.)

Gas-consumers Guide, hand-book of instruction on proper management and economical use of gas; with description of gas-meters, and directions for ascertaining the consumption by meter; on ventilation, etc. Boston. 16 mo., *Alex. Moore.* $0.50.

Gazetteer, The Imperial—. A General Dictionary of Geography—Physical, Political, Statistical, and Descriptive—including comprehensive Accounts of the Countries, Cities, Principal Towns, Villages, Seas, Lakes, Rivers, Islands, Mountains, Valleys, &c., in the World. Edited by W. G. Blackie. With a supplement bringing the information down to the latest dates. Illustrated by nearly 800 Engravings. Two large Vols., including the Supplement, imperial 8vo. Edinburgh. *Blakie & Sons.* £4 15s.

Geology; The Utica slate and related formations. Fossils of the Utica slate and metamorphoses of triarthrus Becki. [Printed in advance of V. 10. Transactions Albany Institute, June, 1879. C. D. Wolcott, Albany. 8vo. *Munsell* $0.50.

Health; The habitation in relation to health. F. S. B. Francois de Chaumont, M. D. Prof. in Army Med School, Netly. London. 8vo. *Soc. Prom. Ch. Knowledge.* 1s.

———,Public Health Reports and Papers. Vol. IV. Presented at the meetings of the American Public Health Association in the years 1877--78. Boston. 8vo. *Houghton, Osgood & Co.*

Heat; The mechanical theory of heat. R. Clausius. Trans, by Walter R. Browne. London. Cr. 8vo. *MacMillan.* 10s. 6d.

———Solar Light and Heat. Z. Allen, New York. 8vo. *Appletons.* $1.50.

Hydraulic Engineering. G. R. Burnell. New ed. rev. and enl by D. K. Clark. (Weales Series.) London. *Crosby, Lockwood & Co.* (Announcement.)

Ice Making Machines. Ledoux, M. Ice-making machines: Theory of action of various forms of cold-producing or so-called Ice Machines (*Machines a froid*); from the French. Reprinted from *Van Nostrand's Magazine.* N. Y. *Van Nostrand.* (Van Nostrand's Science ser. No. 46.) $0.50.

Labor-making machinery. F. P. Powers. New York. 12 mo. *Putnam's.* $0.20.

Machinery. Appleby's illustrated Handbook of —Part IV. Machine Tools. London. *Spons.* (Announcement.)

Machinery and Mill Work, Manual for. W. J. M. Rankine. 4th ed., rev. by W. J. Millar. London. Post 8vo. *Griffin.* 12s. 6d.

Mathematical and Physical Papers. G. G. Stokes, *Cambridge University Press.* (Announcement.)

Mechanics. R. S. Ball. New York. 16mo. *Holt.* $0.60.

Metalliferous Minerals and Mining. D. C. Davies. London. Cr. 8vo, illus. *Lockwood.* 12s. 6d.

Metallurgy. Silver and Gold. Part I. John Percy. London. *Murray.* (Announcement.)

Meteorology, Modern. A Series of Six Lectures delivered under the auspices of the Meteorological Society. By Dr. Mann, F. R. C. S., J. K. Laughton, F. R. G. S., R. Strachan, Rev. W Clement Ley, M. A., G. J. Symons, F. R. S., and R. H. Scott, M. A., F. R. S. London. Cr. 8vo, *Stanford.* 4s. 6d.

Metric System. The Metric System of Weights and measures; address del. before the convocation of the Univ. of N. Y. at Albany, August 1, 1871. F. A. P. Barnard. 3d ed., with add. and ind. of 2,000 references. Boston. 8 vo. *Am. Metric Bureau.* $1.50.

Microscopic Organizations in Cochituate Water. Robert White, M. D. Boston. 8vo illus. *Alex. Moore.* $0.25.

Military Engineering, Instruction in. Vol. 1. part 3. Military Bridges. Compiled at the School of Military Engineering, Chatham, 3rd ed. Adjutant General's Office, Horse Guards. 1st August, 1879. Post 8vo. *British Government Publ.* 3s.

Naval Architect's and Shipbuilder's Pocket Book of Formulæ, Rules and Tables, and Marine Engineer's and Surveyors Handy Book of Reference. C. Mackrow, A. I. N. A. London. 8vo, illus. *Lockwood.* 12s. 6d.

Parks and Gardens of the World. Described and Illustrated. New York. Imp. 4to, illus. *Nelson & Sons.* $6.50.

Penmanship, Ornamental. George J. Becker. Philadelphia. 4to, 50 Plates. *J. W. Queen & Co.* $4.00.

Pipes and Pipe Joints in the Open Trenches, The Testing of, with a description of the Osset Water Works. Malcolm McCulloch Paterson, C. E. London. 8vo, 2 plates. *Spon.* New York. $0.80.

Plumbing. A Text-book to the Practice of the Art or Craft of the Plumber, with chapters upon House Drainage, embodying the latest improvements, by W. P. Buchan. New ed., rev. and extended. 300 illus. (Weale's Series.) London. *Crosby.* 3s. 6d.

Power, Manual of Power. For Machines, Shafts and Belts. With a History of Cotton Manufacture in the United States. By Samuel Webber, C. E. New York. 8vo. *Appletons.* $3.50.

Railways and Locomotives. A Series of Lectures delivered at the School of Military Engineering, Chatham, in the year 1877. *Railways,* by John Wolfe Barry, M. Inst. C. E. *Locomotives,* by F. J. Bramwell, F.R.S., M. Inst. C. E. London. *Longmans.* (Announcement.)

Railway Construction; The Science of; Sir R. Stephens. (Weale's Series.) London. 12mo. *Lockwood.* 4s.

Scientific Terms, Dictionary of: edited by William Rossiter. London and New York. 8vo, illus. *Putnams.* $1.75.

Sewage Disposal. Intermittant Downward Filtration, *per se,* and in Combination with Surface Irrigation. By J. Bailey Denton, M. Inst. C. E 1 vol, 20 pages. 8vo, paper. 1872 and 1879. *Spons.* (New York.) $0.40.

—— —— Report to the Rural Sanitary Authority, Wrexham Union, on the Gravitating Sewerage Scheme (*per se*) intended for Stansty, &c. With Proposals for Sewering the same on "Isaac Shone's Sewerage System." With Plans. London. 8vo. Spons. 2s.

Steam and the Steam Engine—Stationary and Portable. Being an Extension of Mr. John Sewell's "Treatise on Steam," by D. K. Clark, M. I. C. E. 2d ed. corrected, with numerous illus. (Weale's Series.) London. *Lockwood.*

Surveys. Aid to Survey Practice, for Reference in Surveying, Levelling, Setting-out, and Route-Surveys for Travellers, with Formulæ Tables and Illustrations. By Louis D'A. Jackson. Wood engravings and folding plates. London. *Lockwood.* (Announcement.)

Telephone, Microphone and Phonograph. Count du Moncel. Authorized trans., with add. and cor. by author. New York. 12mo, illus. *Harpers.* $1.25.

Terms of Art and Science. G. Bankes Brooke. Philadelphia. 12mo. *Lippincott.* $1.50.

Tin and Tin Plates. A Short Description of Tin Mining and Metallurgy—A History of the Origin and Progress of the Tin Plate Trade, and a Description of the Ancient and Modern Processes of Manufacturing Tin Plates. By P. W. Flower. London. 8vo, illus. *G. Bell & Son.* 10s. 6d.

Tin Mining in Larut. Patrick Doyle. New York. 8vo, illus. *Spons.* $1.50.

Torpedoes and Torpedo Warfare, Offensive and Defensive. Being a complete History of Torpedoes and their application to Modern Warfare. By C. Sleeman, late Lieutenant R. N. and late Commander Imperial Ottoman Navy. Portsmouth, Eng. Royal 8vo, illus. and plates. *Griffin & Co.* 24s.

Tunnel Shafts: A Practical and Theoretical Essay on the Construction of Large Tunnel

Shafts. By J. H. Watson Buck, M. Inst. C. E. With folding plates. London. Royal 8vo. *Lockwood.* (Announcement.)

Wood-Working Machinery: Its Rise, Progress and Construction. With Hints on the Management of Saw Mills, and the Economical Conversion of Timber. Illustrated with Examples of Recent Designs by leading English, French and American Engineers. By M. Powis Bale, C. E., M. I. M. E. London. Large crown, 8vo. *Lockwood.* (Announcement.)

Workshop Companion, The. A Dictionary of Practical Information. John Phin. New York. 12mo. *Industrial Pub. Co.* $0.35.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Administration des Ponts et Chausees, Paris:

Annales, October and November, 1879.

From American Chemical Society, P. Cassamajor, Secretary, New York:

Proceedings of the Society. Vol. 1, No. 10.

From American Institute of Mining Engineers, Thomas M. Drown, Secretary, Easton, Pa.:

Transactions, Vol. I. to VII., inclusive.

From American Iron and Steel Association, James M. Swank, Secretary, Philadelphia, Pa.:

The Cause of our National Prosperity. An address to Congress by the American Iron and Steel Association.

The Wearing Qualities of American Steel Rails.

From Argentine Scientific Society, Don Eduardo Aguirre, Secretary, Buenos Ayres:

Annals of the Society, October, November and December, 1879.

From Hon. Allan Campbell, Commissioner, Dept. Public Works, New York:

Report of the Department for the quarter ending Sept. 30. 1879.

From Thos. Lincoln Casey, Lt. Col. Corps of Engineers, U. S. A., Washington, D. C.:

Report of the Joint Commission created to direct and supervise the completion of the Washington Monument. (2 copies.)

Letter from W. W. Corcoran, Chairman of Joint Commission for the completion of the Washington Monument, showing the extent and progress made in the work and the amount of money expended.

Annual Report of Lieut. Col. Thos. Lincoln Casey, detailing the work done toward the completion of the Washington Monument during the year ending November 30, 1879, together with statement of moneys expended upon the same, and two sheets of tracings, &c.

From Civil Engineers' Club of the Northwest, L. P. Morehouse, Secretary, Chicago:

Proceedings. Vol. IV.

From Clarke, Reeves & Co., New York;

Two framed Photographs of Metropolitan Elevated Railroad at Eighth Avenue, New York City.

From the Department of the Interior, Washington, D. C.:

Annual Report of the Auditor of Railroad Accounts made to the Secretary of the Interior, for the year ending June 30, 1879.

From A. J. Du Bois, New Haven, Conn.:

Upon a New Theory of the Retaining Wall. A. J. Du Bois, Ph. D. Philadelphia. 1879.

From J. Lawrence Smith, Louisville:

Inter-Oceanic Canal. Practicability of the Different Routes and Questionable Nature of the interest of the United States in a Canal. J. Lawrence Smith, Louisville, 1879. (Copies for distribution.)

From Bryant Godwin, New York:

Proceedings of the Special Committee on Railroads appointed under a Resolution of the Assembly to investigate alleged abuses in the management of railroads chartered by the State of New York. Eleven parts.

From Julius E. Hilgard, Assistant in charge, United States Coast Survey, Washington, D. C.:

Methods and Results; on a chart of the Magnetic Declination in the United States. (Copies for distribution.)

Methods and Results; Standards of Measure of the United States compared with those of Great Britain and France. (Copies for distribution.)

From Institution of Civil Engineers, James Forrest, Secretary, London:

Excerpt from Minutes of Proceedings. Edited by James Forrest.

Report of Proceedings at the Annual General Meeting, held December 23, 1879.

Cushing's Reversible Level. Edward H. Courtney.

La Corbiere Lighthouse, Jersey. Imbrie Bell.

Experiments on the Resistance to Horizontal Stress of Timber Piling. John W. Sandeman.

Brief account of the Woosung Railway. Richard C. Rapier.

From Institution of Mechanical Engineers. Walter R. Browne, Secretary, London:

Proceedings. Glasgow meeting, August, 1879.

First Report of Prof. W. C. Unwin to the Sub-Committee of the Institute on the form of Riveted Joints. (2 copies.)

From MM. E Lavoinne and E. Pontzen, Paris:

Les Chemins de fer en Amerique. One volume Text and two atlases of plates.

From McGill University, Henry T. Bovey, Dean of the Faculty of Applied Science, Montreal, Canada:

Annual Calendar and Examination Papers, 1879-80.

From Midland Institute of Mining, Civil and Mechanical Engineers, Joseph Mitchell, Secretary, Barnsley, England:

Transactions. October and November, 1879.

From Prof. Simon Newcomb, Supt. American Ephemeris, Washington, D. C.:

The American Ephemeris and Nautical Almanac for 1882.

From New York Meteorological Observatory, Department Public Parks, Daniel Draper, Director, Central Park, New York:

Abstract from Self-Recording Instruments. November, 1879.

Annual Report of the Director for year ending Dec. 31, 1878.

From Joseph Nimmo, Jr., Chief of Bureau of Statistics, Washington, D. C.:

Annual Report of the Chief of Bureau of Statistics on the Foreign Commerce of the United States for the year ending June 30, 1879.

From North of England Institute of Mining and Mechanical Engineers, Theo. Wood Bunning, Secretary, Newcastle-on-Tyne, England:

List of Members, Rules, Barometer Readings, Index, Vol. XXVIII., &c.

Transactions. September and October, 1879.

From Charles Paine, Gen. Supt. L. S. and M. S. R. R., Cleveland, Ohio:

Seventh Annual Report of the Commissioner of Railroads of the State of Michigan, for the year ending Dec. 31, 1878. Lansing, 1879.

Thirty-second Report of the Ohio State Board of Agriculture, with an abstract of the proceedings of the County Agricultural Societies to the General Assembly of Ohio, for the year 1877. Columbus, 1878.

Michigan Railroads. Comparative Summary from returns for 1877 and 1878, showing percentages of increase and decrease.

From the Publishers Revue Générale des Chemins de fer, Edgar Monjean, Secretary, Paris:

Revue Générale des Chemins de fer. September and October, 1879.

From Charles Ward Raymond, New York:

Four Photographs of the Metropolitan Elevated Railroad at 110th St. and Eighth Ave., New York City.

From Francis Rinecker, Wuerzburg, Germany:

Oeconomie im Brücken-Maurwerk. F. Rinecker.

From Royal United Service Institution, Capt. B. Burgess, Secretary, London:

Journal of the Institution. Vol. XXIII. No. CII.

From Thomas C. Ruggles, New York:

Annual Address of the President of the New York Produce Exchange, with accompanying Documents, May 27, 1879.

From Thomas S. Sedgwick, Washington, D. C.:

The Compressed Asphalt Block Pavement. Its Uses, Merits, and mode of Manufacture. (3 Copies.)

From Société des Ingenieurs Civils, M. Mallett, Secretary, Paris:

Memoires de la Société. September and October, 1879.

From St. Louis Public School Library, Fred. M. Crunden, Librarian, St. Louis:

Bulletin of the Library. List of Additions. January to June, and July to August, 1879.

From Joseph W. Turtle, Newark, N. J.:

Congressional Directory, Forty-sixth Congress (Second Session). Corrected to December 6, 1879.

From United States Light House Board, Washington, D. C.:

List of Beacons, Buoys, Stakes, Spindles, and all other Day Marks in the Second Light House District. Corrected to July 1, 1879. (2 Copies.)

List of Beacons, Buoys, Stakes and other Day Marks in the Eighth Light House District. Corrected to December 31, 1879. (2 Copies).

List of Beacons, Buoys, Stakes, Spindles, and other Day Marks in the Twelfth Light House District. Corrected to December 31, 1879. (2 Copies.)

From United States Naval Observatory, Washington, D. C.:

Narrative of the Second Artic Expedition made by Charles F. Hall. Prof. J. E. Nourse, U. S. N. Washington, 1879.

From Welton and Bonnett, Waterbury, Conn.:

Thirteenth Report of the Board of Water Commissioners of the City of Waterbury, Conn., Dec. 31, 1879.

From John Wiley & Sons, New York:

Experiments on the Strength of Wrought Iron and of Chain Cables. Commander L. A. Beardslee, U. S. N. Edited by Wm. Kent.

From Gen. G. K. Warren, Corps of Engineers, U. S. A., Newport, R. I.:

Report on Bridging the Mississippi between St. Paul, Minn., and St. Louis, Mo. Gen. G. K. Warren. Washington, 1878. (Copies for distribution.)

From Gen. Horatio G. Wright, Chief of Engineers, U. S. A., Washington, D. C.:

Report of Board of Engineers in relation to bridge over Detroit River, &c.

Reports of Survey of Chattahoochee, Etowah and Duck Rivers. Maj. W. R. King.

Reports of Surveys of Cowlitz River, Washington Territory and Umpqua River and Alsea Harbor and Bar, Oregon; also a Survey of Bar at mouth of Columbia River. Maj. G. L. Gillespie.

Report of Survey of Cuivre River, Missouri. Capt. A. Mackenzie.

Special Report touching progress made in building north wing edifice for use of the Department of State, War and the Navy, &c. Lt.-Col. Thos. Lincoln Casey.

Reports of Moose-a-bec Bar, Cathance River Jonesport, Me., and of the outlet of Lake

Winnepesaukee, New Hampshire. Col. George Thom.

Reports relating to a harbor of refuge at entrance to Portage Lake and Lake Superior Ship Canal and Bayfield and Ashland Harbors, Wisconsin, and Manistique River, Mich. Maj. H. M. Robert.

Report of Survey of Falls on Red River, La., and of Black River, Ark., and of Tchula Lake and Yallabusha River, Miss. Maj. W. H. H. Benyaurd.

Report giving an account of the construction of a sluiceway at the Falls of St. Anthony, Minn., and urging the importance of immediate repairs to the apron built by the Government of the United States for the preservation of the Falls. Capt. C. J. Allen.

Recommendations for a special appropriation for the improvement of the Tenessee River. Maj. W. R. King. (2 Copies.)

Report of Survey to estimate the damage done to the Town of Venice, Ill., by reason of the Government improvements on the Mississippi River. Col. J. H. Simpson.

Letter from W. W. Corcoran, Chairman of Joint Commission for the completion of the Washington Monument, showing the extent and progress made in the work, and the amount of moneys expended. (Several copies.)

Surveys of Waukegan Harbor, Ill., and Oconto and Wolf Rivers, Wisconsin. Maj. D. C. Houston. (2 copies.)

From other sources :

The Interoceanic Canal. Count Ferdinand de Lesseps. North American Review for January, 1880.

The Library Journal, Vol. IV., Nos 11 and 12.

Annual Report of the State Engineer and Surveyor on the Canals of the State of New York for 1877.

ANNOUNCEMENTS.

The Twelfth Annual Convention of the Society will be held at St. Louis during the week beginning May 24th, 1880. The local committee at St. Louis is already engaged in preparation, and is in correspondence with the Secretary as to the details, which will be announced by circular to the members of the Society.

After the meeting of the Society of February 26th, at which M. de Lesseps and the engineers accompanying him took part in the discussions on the subject of Inter-Oceanic Canal Projects, a reception was given to these gentlemen by subscribing members. This reception was in the hall attached to the Theatre of the Union League Club and gave a pleasant opportunity to the members present and their friends of personally meeting M. de Lesseps and his associates, who had just returned from the Isthmus of Panama. All these gentlemen were present, including Mr. J. Dirks, Engineer of the Waterstaat of Holland, and of the canal from Amsterdam to the sea, Mr. V. Dauzats, Engineer of the Suez Canal, Mr. Edmond Boutan, Engineer of the Corps of Mines, Lieut.-Com. L. N. B. Wyse, Mr. A. Couvreux *fils*, and others.

The American Institute of Mining Engineers held its Annual Meeting on February 17th, 1880, at the House of the American Society of Civil Engineers in New York.

The following resolution was adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications :

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door east from Fourth avenue, and near the southwest corner of Gramercy Park. It is open from nine o'clock A.M. to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P.M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P.M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings, both for consultation of books and periodicals and for conversation.

LIST OF MEMBERS.

ADDITIONS.

HONORARY MEMBERS.

		Date of Election.
WRIGHT, HORATIO G.	Chief of Engineers, Brig. and Bv't Maj.-Gen'l U. S. A., Washington, D. C.	March 3, 1880.

MEMBERS.

CHAPHE, ANDREW J.	Chief Mechanical Engineer St. Louis Water Works, St. Louis, Mo.	February 4, 1880.
MOORE, CHARLES E.	6 Kellogg Street, Syracuse, N. Y.	January 7, 1880.

ASSOCIATE.

WHEATON, EDWARD.	Naragansett Hotel, Providence, R. I.	February 4, 1880.

CHANGES AND CORRECTIONS.

MEMBERS.

JUDSON JOHN A. ..... (Frank B. Porter & Co.) Bellevue Ave., Newport, R. I.

RINECKER, FRANCIS. ..... Civil Engineer, Rieneck, Bavaria.

SCOVILL, E. TRACY. ..... Ass't Engineer Northern Pacific Railroad, Walla Walla, Washington Territory.

STEPHENS, CLINTON F. ..... Chief Engineer Texas and St. Louis Railroad, Texarkana, Ark.

WARFIELD, ALBERT G., JR. .. 508 Second St., San Francisco, Cal.

JUNIOR.

CORNELL, GEORGE B. ..... Ass't Engineer Brooklyn Elevated Railroad, 31 Fulton St., Brooklyn, N. Y.

RESIGNATION.

BROWN, ROBERT N. ..... Elected member Dec. 1, 1852. Resigned Feb. 21, 1880.

DEATH.

THOMPSON, JOHN C. ..... Elected member May 18, 1870. Died Jan. 17, 1880.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VI.—March, 1880.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

March 3d, 1880.—The Society met at 8 P. M. Vice-President Chanute in the chair. The discussion upon the subject of Inter-Oceanic Canal projects was resumed.

M. J. Dirks, Engineer of the Waterstaat, of Holland, read a paper in reference to the prices fixed by the Paris Congress for various kinds of work on the proposed canal at Panama, giving reasons why they were not considered too low. He also, in answer to questions, presented details of the results of examinations made on the line of the proposed canal by the Engineers recently returned from the Isthmus.

M. A. Couvreux *fils*, gave an interesting account of the various steps in the conduct of the enterprise by M. de Lesseps and others for securing full information as to the proposed canal, including the preliminary operations in France, and the subsequent work on the Isthmus, giving detailed information as to the organization of the parties making the survey and of their work on the line between the two oceans.

Mr. Ashbel Welch presented considerations as to the question of the relative economy of a canal with or without locks.

The appointment as Honorary Member of the Society of General H. G. Wright, Chief of Engineers, U. S. Army, was announced.

Ballots for admission to membership were canvassed, and the following were declared elected: as Members, Thomas S. Anderson, Greenville, Miss.; Anthony H. Blaisdell, St. Louis, Mo.; Morris M. Defrees, Indianapolis, Ind.; William H. Greenwood, Denver, Col.; William H. Heuer, Captain Corps of Engineers, U. S. A., Key West, Fla.; Robt. E. McMath, St. Louis, Mo.; Isaac Newton, New York; Robert A. Shailer, Wilmington, Del.; Charles A. Sweet, Syracuse, N. Y.; Christopher C. Waite, Zanesville, O. As Associate, Joseph W. Putnam, New Orleans, La.

March 17th, 1880.—The Society met at 8 P. M. President Fink in the chair.

Mr. Charles Macdonald presented a paper in continuation of the discussion on Inter-Oceanic Canal Projects, and the subject was further discussed by Messrs. Welch, Chanute, J. C. Campbell, Prindle and Bogart.

MEMOIRS OF DECEASED MEMBERS.

GEORGE W. EDGE,* Member A. S. C. E.

Died January 1st, 1880.

Mr. Edge was born in Jersey City, New Jersey, February 22d, 1811, and died January 1st, 1880. His parents were Isaac and Frances Edge, who settled in Jersey City in the year 1804.

Mr. Edge became a member of the American Society of Civil Engineers June 11th, 1874.

Early in life Mr. Edge studied and became an expert in the science of chemistry, which afterwards, in his business as a gas engineer, was of great service to him. In the year 1852 he was waited upon by parties owning the gas works in Jersey City, and asked to become their manager and engineer. After many misgivings as to his ability to manage a gas works, he accepted the proposal and entered upon the duties, which only ceased with his life.

When Mr. Edge commenced his labors as a gas engineer, clay retorts were not used in this country, the retorts being of cast-iron set in benches of threes, and supported on bars of cast-iron, in some cases extending entirely across the bench, in other settings the bearing bars extended from a brick pier carried up to the necessary height, and were

* Committee to prepare memoir, Eugene Vanderpool, James H. Armington.

placed under one retort only. Plates of cast-iron were used to protect the batteries of the retorts from the heat, and the whole arrangement of the bench was in a crude state. The works were found entirely out of order, and the supply of gas to the consumers was very irregular. This state of affairs was very unpleasant to Mr. Edge and not profitable to the company. Mr. Edge's ingenious mind soon devised a plan of relief from this condition, and as soon as the necessary material could be procured he energetically had carried out alterations and improvements which prevented any future difficulty in the supply of gas to the consumers. At the same time the improvements were a source of much profit to the company. During the time that Mr. Edge was engaged as a manager of gas works his mind was constantly occupied with plans for the improvement of the apparatus used, and for a more perfect system for the economical production and distribution of gas.

The results of his study he practically applied, and it is not too much to say that many gas engineers in this country have been instructed by advising with him. It is certain that many companies, both in this country and abroad, have profited by the use of apparatus designed and improved by him.

Mr. Edge was always ready to impart his knowledge to others, and it seemed to give him much pleasure to meet with those of his profession, and to speak and advise in reference to the theory and practice of the manufacture of gas.

Mr. Edge's modest estimate of his abilities, as evinced by his diffidence in accepting the position of the engineer of the Jersey City Gas Company, and of other positions that were forced upon him, was a characteristic trait of the man, fully recognized by his friends. He was a man of marked ability, but extremely modest in claiming recognition for his inventions and services.

Mr. Edge was not only widely known as a gas engineer, but was known at home, in Jersey City, as a leading man, a good citizen, a warm friend, and wise counsellor. He has left an enviable reputation as a consolation for his relatives and friends.

ANNOUNCEMENTS.

THE TWELFTH ANNUAL CONVENTION of the Society will be held at St. Louis, Mo., beginning Tuesday, May 25th, 1880.

Sessions for the consideration of professional subjects, and one for the transaction of business, will be held.

The details of the programme will be announced as soon as determined by the local committee.

The following is a list of topics to be considered with reference to papers published in Transactions during the preceding year :

CLXXV. (*Jan.* 1879.) The Flow of Water in small Channels, after Ganguillet and Kutter, with Kutter's Diagram modified, and Graphical Tables with special reference to Sewer Calculations.—R. Hering.

CLXXVI. (*Jan.*) The permanent Way of

Railways in Great Britain and Ireland, with especial reference to the use of Timber, Preserved and Unpreserved, Compiled from information received from Engineers in charge of those Railways.—John Bogart.

CLXXVII. (*Feb.*) Experiments on the Resistances of Rolling Stock. Made under the direction of Charles Paine.—A. M. Wellington.

CLXXVIII. (*March.*) Light-house Engineering as displayed at the Centennial Exhibition.—John G. Barnard.

CLXXIX. (*April.*) Minot's Ledge Light-house.—B. S. Alexander.

CLXXX. (*May.*) The Construction and Maintenance of Roads.—Edward P. North.

CLXXXI. (*June.*) Flexure and Transverse Resistance of Beams.—Charles E. Emery.

CLXXXII. (*July.*) On the Flow of Water in Rivers.—De Volson Wood.

CLXXXIII. (*Aug.*) The South Pass Jetties. Notes on the Consolidation and Durability of the Works, with a description of the Concrete Blocks and other Constructions of the last year.—Max E. Schmidt.

CLXXXIV. (*Sept.*) The Ocean Pier at Coney Island.—Charles Macdonald.

CLXXXV. (*Sept.*) Stability of Stone Structures.—William H. Searles.

CLXXXVI. (*Oct.*) The Use of Steel for Bridges.—Theodore Cooper.

CLXXXVII. (*Oct.*) The Construction of the Atchison, Topeka and Santa Fè Railroad over the Raton Mountains, and the Performance of Locomotives on its Steep Grades.—James D. Burr.

CLXXXVIII. (*Nov.*) Inter-Oceanic Canal Projects.—A. G. Menocal.

January, February, March, 1880.—Inter-Oceanic Canal Projects, by Walton W. Evans, Frederick M. Kelley, Charles A. Sweet, John C. Campbell, Charles D. Ward, Nathan Appleton, S. F. Shelbourne, Max E. Schmidt, Thomas J. Long, Edward P. North, Ashbel Welch, Julius W. Adams, F. de Lesseps, J. Dirks, V. Dauzats.

Also papers in continuation of the discussion on Inter-Oceanic Canal Projects, by A. Couvreux *fils*, Charles Macdonald, and others, will be printed before the date of the Convention.

CLXXXIX. (*March.*) Engineering Problems Involved in the Proposed Improvement of the Erie Canal, by Increasing the Depth of its Channel One Foot. By E. Sweet, Jr.

The following papers also will be printed and ready for distribution before the time of the Convention :

Note on Kutter's Diagram. By Charles H. Swan.

The New York and Brooklyn Bridge Approaches and Superstructure. By F. Collingwood.

Experiments with Apparatus for Testing Cements, by Alfred Noble, with discussion on testing cement by F. Collingwood, D. W. Cunningham, C. Latimer, F. O. Norton, F Rinecker, W. Sooy Smith, D. J. Whittemore.

Design and Construction Table for Egg-shaped Sewers. By C. G. Force.

The Preservation of Timber. By J. W. Putnam.

On the Variation due to Orthogonal Strains in the Elastic Limit in Metals, and on its Practical Value and more important applications. By R. H. Thurston.

Members of the Society are earnestly requested to furnish information or memoranda upon any of the subjects referred to. They are also invited and expected to take part in the discussions, either in person or by sending to the Secretary notes for presentation. In either case it will assist the committee in arranging the details for sessions of the Convention, if members expecting to take part in the discussions will notify the Secretary at once to that effect.

Excursions by river and by rail from St. Louis are contemplated, and the arrangements for them are in progress. The Secretary is instructed to state that it is permissible that members of the Society should be accompanied by their families.

Under the rule adopted by the Society in reference to invitations to Conventions, the members of other engineering organizations; also the editors of professional journals exchanging with this Society will be invited to attend the Convention and the Excursions connected therewith.

The details of arrangements are now being perfected, and will soon be announced.

Please notify the Secretary whether you will attend the Convention, and whether you will present a paper or take part in special discussions.

The following resolutions were adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications :

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of the differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door east from Fourth avenue, and near the southwest corner of Gramercy Park. It is open from nine o'clock A.M. to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P.M.

The Library and Conversation Rooms will also, for the present, be open every *Thursday evening*, from 7½ to 10 P.M. Members are invited to avail themselves of the opportunities afforded on Thursday evenings, both for consultation of books and periodicals and for conversation.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

	Date of Election.
BLAISDELL, ANTHONY H....U. S. Assistant Engineer, 1351 Washington Avenue, St. Louis, Mo....	March 3, 1880.
CHAPHE, ANDREW J. .....Chief Mechanical Engineer, Water Works, St. Louis, Mo.....	February 4, 1880.
McMATH, ROBERT E.....U. S. Assistant Engineer, 404 Market St., St. Louis, Mo.....	March 3, 1880.
NEWTON, ISAAC..... .. Engineer, Kemble Coal and Iron Co., P. O. Box 157, New York City, N. Y.....	March 3, 1880.
SWEET, CHARLES A .....Syracuse, N. Y.....	" "
VAN BROCKLIN, MARTIN.....Chief Engineer, Tehuantepec Railroad, Coatzacoalcos, Mexico.....	January 7, 1880.

CHANGES AND CORRECTIONS.

MEMBERS.

HARROD, BENJAMIN M.....Member Mississippi River Commission, New Orleans, La.

HAYWARD, JAMES A. .... .U. S. Engineer's Office, Box 900, Galveston, Texas.

MENOCAL, ANICETO G.....Civil Engineer, U. S. N., Managua, Nicaragua.

PETTIT, ROBERT E.....Principal Ass't Engineer, Penna. Railroad, Altoona, Pa.

CHANGES AND CORRECTIONS.

MEMBERS.

RICE, EDWARD C.....Chief Engineer, Louisville, New Albany and St. Louis Railway, 3649 Baker Ave., St. Louis, Mo.

ROCKWELL, SAMUEL.....Boreel Building, 115 Broadway, Room 84, New York City, N. Y.

ROTCH, WILLIAM.....New Bedford, Mass.

ASSOCIATE.

FORD, ARTHUR L.....Care Panama RR. Co., 37 Wall St., N. Y. City, N. Y.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VI.—April, 1880.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

April 7th, 1880.—The Society met at 8 p. m. Vice-President Chanute in the chair. Ballots for admission to membership were canvassed and the following declared elected : as Members, George S. Field, of New York ; Lorenzo M. Johnson (elected Junior, March 3d, 1875), of St. Louis, Mo. ; Henry G. Morse, of Youngstown, O. ; Horatio Seymour, Jr. (elected Associate, Jan. 8th, 1873), of Albany, N. Y. ; Charles A. Smith, of St. Louis, Mo.—as Junior, George H. Pegram, of St. Louis, Mo.

A discussion on the subject of Inter-Oceanic Canal projects by T. C. Clarke was, in the absence of the author, read by the Secretary. A letter on the same subject from Lt.-Commander L. N. B. Wyse was also read, and discussion followed by Geo. W. Dresser and O. Chanute.

A paper on the Variation due to Orthogonal Strains in the Elastic Limit in Metals, and on its Practical Value and more important applications, by R. H. Thurston, was, in the absence of the author, read by the Secretary and discussed by Robert Briggs.

MEMOIRS OF DECEASED MEMBERS.

ALFRED WINGATE CRAVEN, Past-President, A. S. C. E.

DIED MARCH 27TH, 1879.

Alfred Wingate Craven, the second son of Tunis Craven, was born at the Washington, D. C., Navy-yard, October 20th, 1810. The family had been long connected with the navy. His grandfather, Commodore Tingey, was then in charge of this yard, and later his elder brother, the present Admiral T. T. Craven, and younger brother, Capt. T. A. M. Craven, who went down in command of the "Tecumseh" at the battle of Mobile Bay, adopted the naval profession. By the regulations of the service the family was transferred to the navy-yard at Portsmouth, N. H., and Alfred was sent to school at Exeter and Berwick, and when about thirteen years old was entered at Yale College. His connection with the college was severed after about one year, and he was then entered at Columbia College, and there graduated.

After leaving college he studied law, was admitted to the bar, and opened an office in the City of New York. This profession he soon left for the more congenial out-door life of the Civil Engineer.

From December, 1835, till about the same date of the following year he was engaged in the surveys and construction of the Mad River Railroad in Ohio. From Ohio he went to South Carolina, and was engaged three years on the Louisville, Cincinnati & Charleston Railroad, on surveys and construction, having sole charge of the first division of that road from its commencement to its completion.

He then became an assistant of Major G. W. Whistler on the Boston & Albany Railroad, and was transferred thence to the post of First Assistant on the Central Division of the Erie Railway, where he continued till the work was suspended in 1842.

He was next engaged on the Mohawk & Hudson Railroad as First Assistant and afterwards as Chief Engineer in the change of location and removal of the inclined planes at Schenectady and Albany, which position he left in consequence of his refusal to assent to management which he considered inconsistent with professional honor.

He next took charge of the construction of the wharves, docks and basins of the Reading Railroad on the Delaware River. From there he was transferred to the position of Chief Engineer of the Schuylkill Valley Railroad, to which was soon after added the duties of the same position of the Mine Hill Navigation & Railroad Company, both of which he completed and took charge of, till the health of his family necessitated a removal to a more southerly climate, when he resigned and took charge of the work on the Camden Branch in South Carolina. Having finished this work, he was offered the charge of the Columbia & Charlotte Rail-

road, but declined, returned to the City of New York, and received the appointment of Chief Engineer and Commissioner of the Croton Aqueduct Department, July 17, 1849. His experience in construction enabled him to bring into practice in this department a system of hydraulic constructions which have become models of this kind of work for the profession. Mr. Craven brought to his new position a wonderful physique, an intimate understanding of men, great executive ability and uncompromising honesty. During his administration of this office the water service was much extended, the large receiving reservoir in the Central Park was built, surveys of the water-shed of the Croton were made, the large catch-basin at Boyd's Corner commenced, and the introduction of the large main and the pumping engine at High Bridge were contracted for. The sewers were transferred to the Croton Department, and the present system of sewers inaugurated. Reservoirs on Blackwell and Ward's Island were built, with pipe-services from the city. He continued in the duties of this office, under varied political organizations, with credit to himself and to the benefit of the city, till May 1st, 1868, when he resigned, and with his family made an extended tour through Europe.

While occupying the position of Chief Engineer of the Croton Department it may be said that there was hardly any important scheme for the supply of water to cities and towns in which his advice was not asked, either officially or by his engineer friends in charge of the works, and the latter were under many obligations to him for the prompt and extended replies which he gave them. He was the Consulting Engineer of the Brooklyn Water-works, made a report on water-works for the City of Augusta, Ga., reported on and constructed water-works at Savannah, Ga., was Consulting Engineer for the construction of a quarantine hospital, Advisory Engineer to the Department of Public Charities and Correction, to the Fire Department, Rifle Range Association and Yacht Club; in fact, with regard to anything of public interest in the city, his advice was always asked, and his influence considered of the utmost importance. His resignation was regretted as "a loss to the city of one of the most capable, upright and useful public officers ever connected with any department of the city government."

On his return from Europe Mr. Craven opened an office in this city as a Consulting Engineer, and became one of the Commissioners on the Fourth Avenue Railroad Improvement, Chief Engineer of the Syracuse Water-works, Consulting Engineer of the Newark and Brooklyn Water-works and the Gilbert Elevated Railroad.

Failing in health, he went to England in April, 1878, where his disease was further developed, and he died at Chiswick, of cerebral softening, March 27th, 1879.

Few men in this country have occupied a larger space in the engineering profession, and very few have contributed so much to give char-

acter and standing to it as a profession. He was identified with the very first efforts to form an American Society of Civil Engineers, and attended a meeting of Engineers in Augusta, Ga., by whom a call was made for a convention at Baltimore, Feb. 13, 1839, to form an Engineer Society. He was among the first to form the present American Society of Civil Engineers, in 1852, and at the reorganization in 1868 became one of its Directors, and was President of the Society from November, 1869, till November, 1871.

To conclude, a very fair estimate of the character of Mr. Craven may be drawn from an extract of a communication of his to the New York Tribune, on an attempt by the Common Council to have some sewer work paid for, which the Croton Department would not accept, as the contract had not been complied with:

"As Chief Engineer and one of the heads of this Department, I am placed here in charge of certain interests of the property holders and people generally of this city. If by any illegal or corrupt act injustice be done to them in any matter in the most remote degree connected with this Department, I deem it due to them and myself not to be content with the mere requisition of the law, but to perform my full duty in the protection of *their* rights and in the preservation of the integrity of the Department on which they rely; and I do so *with a full sense of my responsibilities, personally and officially.*"

The key-note of his character was his outspoken convictions, with a full sense of his personal and official obligations. Holding what is deemed by many a political office, and almost always in party affiliations opposed to the dominant party in the city, he secured their esteem and maintained his position and the integrity and character of his Department. Among his old friends he was designated as the "Bayard of the Engineer profession."

ADDITIONS TO

LIBRARY AND MUSEUM.

From American Academy of Arts and Sciences, Boston:

Proceedings. Vol. VII. New Series. Part I. From May, 1879, to December, 1879.

From American Chemical Society. P. Cassamajor, Secretary, New York:

Journal of the Society. Vol. I. No. 11.

From American Institute of Mining Engineers. Dr. Thomas M. Drown, Secretary, Easton, Pa.:

A new Air-Compressor. E. Gybbon Spilsbury.

Atmospheric Oxidation, or Weathering of Coal. Dr. James P. Kimball.

The new Coalfield of West Virginia. S. Fisher Morris.

A new method of Dredging, applicable to some kinds of Mining operations. R. W. Raymond

Note on the Defreest Journal Bearing. J. C. Platt, Jr.

The Law of Fatigue and Refreshment of Metals. Dr. Thomas Egleston.

Silver Islet. Thomas Macfarland.

From American Iron and Steel Association. James M. Swank, Secretary, Philadelphia, Pa.:

A memoir of Henry C. Carey, read before the Historical Society of Pennsylvania. Philadelphia, Jan. 5, 1880. William Elder.

The Duty on Steel Rails. The case for the

Manufacturers, at a hearing before the Ways and Means Committee of the House of Representatives, at Washington, Feb. 3, 4 and 5, 1880.

From George D. Ansley, City Surveyor, Montreal:

Report of the City Surveyor of the various works executed by the Road Department of the City of Montreal during the year 1879.

From Argentine Scientific Society. Don Eduardo Aguirre, Secretary, Buenos Ayres.

Annals of the Society. January, 1880.

From Nathan Appleton, Boston:

Consideration of the Inter-Oceanic Canal Projects. How American Interests were misrepresented. M. de Lesseps and his opponents. N. Appleton, in Supplement of *Boston Herald*.

From John W. Bacon, Danbury, Conn.

Biennial Report of the Commissioners of Transportation of the State of California for 1877 and 1878.

Twenty-seventh Annual Report of the Railroad Commissioners of Connecticut, 1879.

Second Annual Report of the Board of Railroad Commissioners of the State of Iowa, 1879.

Report of Railroad Commissioners of the State of Maine for 1879.

Report of the Commissioners on Railroads of Michigan for 1877 and 1878.

Annual Report of the Railroad Commissioner of the State of Wisconsin for 1877–1878.

From Wm. S. Barbour, City Engineer, Cambridgeport, Mass.

Report of the Special Committee on the Water Supply of the City of Cambridge, Mass. December, 1879.

From Charles E. Billin, Philadelphia :

Dephosphorization of Iron. F. Gautier. (3 copies.)

From Board of Supervisors of San Francisco, San Francisco, Cal.

Municipal Reports of the City of San Francisco for fiscal year 1878–79.

From Boston Society of Civil Engineers. George S. Rice, Secretary, Boston.

Constitution and By-Laws, List of Members, Committees, &c., of the Society.

Reports of Proceedings—September, October, November and December, 1879, January and February, 1880.

From Boston Public Library. Mellen Chamberlain, Librarian, Boston.

Bulletin of the Library. January, 1880.

From Bureau of Education, Washington, D. C.:

Circulars of the Bureau, No. 5. 1879.—American Education, as described by the French Commission to the International Exhibition, 1876.

From J. Vincent Brown, Quebec, Canada;

Report of Quebec Railway and Harbor Works. Nos. 1 and 2.

From Hon. Allan Campbell, Dep't Public Works, New York:

Report of the Department for the Quarter ending September 30, 1879.

From H. Wadsworth Clarke, Syracuse, N. Y :

Journal of the Board of Supervisors of the County of Onondaga, N. Y., for 1879.

From Martin Coryell, Lambertsville, N. J.:

Third Annual Report of Lambertville Water Company.

From Gen. George W. Cullum, New York:

Biographical sketch of Major-General Richard Montgomery, of the Continental Army. Gen. Geo. W. Cullum, New York, 1876.

Biographical sketch of Captain William H. Swift, of the Topographical Engineers, U. S. A., 1832–1849. Gen. Geo. W. Cullum, New York, 1880. (2 copies.)

Biographical sketch of Brig.-General Joseph G. Swift, Chief Engineer, U. S. A. July 31, 1812, to November 12, 1818. Gen. Geo. W. Cullum. New York. 1877.

From Joseph P. Davis, Boston:

Annual Report of the City Engineer for the year 1879.

General Specifications for Pumping Engines to govern designs accompanying proposals for Improved Sewerage of Boston.

Sixty-eight Blue prints illustrating Improved Sewerage of Boston.

From Engineers' Club of Philadelphia, Charles E. Billin, Secretary, Philadelphia:

Proceedings. Vol. 1. No. IV.

From Engineer Department, District of Columbia, Washington, D. C.:

Annual Report of the operations of the Engineer Department of the District of Columbia for 1879.

From Engineers' Society of Western Pennsylvania. James H. Harlow, Secretary. Pittsburgh, Pa.:

Description of a Derrick used at Davis Island Dam. James H. Harlow.

Why does Steel Harden? Wm. Metcalf.

From Walton W. Evans, New York:

American *versus* English Locomotives. Correspondence, criticism and commentary respecting their relative merits. New York, 1880. (Copies for distribution.)

From Maj. F. U. Farquhar, Washington, D. C :

Annual Report of the Light-house Board to the Secretary of the Navy for the fiscal year ending June 30, 1879.

From F. G. Field, London, England :

The Notching of Steel Rails. F. G. Field.

From Albert Fink, New York :

Argument before the Committee of Commerce of the House of Representatives of the United States on the Reagan Bill for the regulation of interstate commerce. January 14, 15 and 16, 1880. Albert Fink. (2 copies.)

From Robert Fletcher, Hanover, N. H.:

Annual Report of Atchison, Topeka and Santa Fé Railroad. 1877 and 1878.

Thirty-third and Thirty fourth Annual Report of the Northern Railroad of New Hampshire.

Annual Report of the Manchester and Lawrence Railroad for 1879.

Annual Report of Louisville and Nashville Railroad for 1878–9.

Annual Reports of Worcester and Nashua Railroad for 1878 and 1879.

From George H. Frost, *Engineering News*, New York:

Railroad Engineers' Practice. Thomas M. Cleemann. New York, 1880.

From Senor F. de Garay, Mexico:

Ferrocarril de Tehuantepec. Mexico, 1879.

Informe sobre el Reconocimiento del Istmo de Tehuantepec. Manuel Fernandez. Mexico, 1879.

From F. H. Garrett, Baltimore, Md.:

A Bibliography of the Baltimore and Ohio Railroad from 1827 to 1879. John W. M. Lee. Baltimore, 1879.

From Geographical Society of Dresden, Germany:

Sixteenth Annual Report of the Geographical Society of Dresden. Scientific part. (German.)

From Charles O. Gleim, Cologne, Germany:

Zeitschrift für Baukunde. Parts 1, 2, 3 and 4. 1879.

From Hon. A. A. Haggett, Lowell, Mass.:

Seventh Annual Report of the Lowell Water Board.

From A. E. Hall, Boston;

Specifications forming part of Letters Patent on an Improvement in Transporting and delivering Dredged Material. A. E. Hall.

Two framed Photographs of Apparatus for transporting and delivering Dredged Material. Patented Dec. 9, 1879, by A. E. Hall.

From Hungarian Society of Engineers and Architects, Buderpest:

Transactions—November and December, 1879. January and February, 1880.

From Willaim R. Hutton, Baltimore, Md.:

Annual Report of the Harbor Board for 1879.

From Institution of Civil Engineers, James Forrest, Secretary, London:

Address of the President, William Henry Barlow. January 13, 1880.

Abstract of papers in Foreign Transactions and Periodicals. Vol. LIX. Session 1879–80. Part 1.

List of Members of the Institution.

Account of Two Drainages in Ireland. John Hill.

From Institution of Mechanical Engineers, Walter R. Browne, Secretary, London:

Proceedings. October, 1879. Index. List of Members.

From Thomas C. Keefer, Ottawa, Canada:

Handbook and Official Catalogue of the Canadian section, Paris Universal Exhibition. 1878. Compiled and Edited by Thomas C. Keefer.

From John Kennedy, Montreal, Canada:

Annual Reports of the Harbor Commissioners of Montreal for 1879. (2 copies.)

From William Metcalf, Pittsburg:

Why does Steel Harden? (Copies for distribution.)

From Henry Mitchell, Boston:

An Inspection of the terminal points of the Proposed Canals through Nicaragua and the Isthmus of Darien. Prof. Henry Mitchell. Washington, 1880.

From North of England Institute, Mining and Mechanical Engineers. Theo. Wood Bunning, Secretary, Newcastle-on-Tyne, England:

Transactions. Vol. XXVIII.

From P. A. Peterson, Montreal, Canada:

General Specifications and form of tender for the Iron Superstructure of the Chandiere Bridge.

From E. Prince, Quincy Ill.:

Fourth revised list of Water Works in the United States and Canadas. Edward Prince, Quincy, Ill. (2 copies.)

From the Publishers Revue Générale des Chemins de fer, Edgar Monjean, Secretary, Paris:

Revue Générale des Chemins de fer. November and December, 1879.

From Wm. Rotch, New Bedford, Mass.:

Sixth Annual Report of the Watuppa Water Board. Fall River, Mass., 1880. (2 copies.)

From Royal United Service Institution, Capt. B. Burgess, Secretary, London:

Journal of the Institution. Vol. XXIII. No. CIII.

From Wm. B. Sherman, New Bedford, Mass.:

Tenth Annual Report of the Acushnet Water Board. New Bediord, 1880.

From T. Guilford Smith, Buffalo, N. Y.:

Report of President and Managers of Philadelphia and Reading Railway Company for 1879.

From Société des Ingenieurs Civils, M. Mallet, Secretary, Paris:

Memories de la Societé. November and December, 1879.

From the Society of Civil Engineers of Portugal, Lisbon:

Transactions. November and December, 1879.

From St. Louis Public School Library, Fred. M. Crunden, Librarian, St. Louis:

Annual Report of the Library for 1879.

From E. Sweet, Jr., Albany, N. Y.:

Report on the New York Elevated Roads. E. Sweet, Jr. Albany, 1880.

From H. D. Tiffany, New York:

Illustrations of the Croton Aqueduct. F. B. Tower. New York, 1843.

Spring Water *versus* River Water for supplying the City of New York, containing a compendius examination of the internal supplies, the method and actual expense of obtaining them. M. Hale. New York, 1835

An examination of the Water Commissioners' Report of the City of New York of November, 1833, refuting many of the objections therein contained, and exhibiting errors in their estimate of expense for procuring water on the island of more than $2,000,000. M. Hale. New York, 1835.

From D. Torrey, New York:

Statistical Atlas of the United States based on the results of the Ninth Census, 1870. Francis A. Walker. New York, 1874.

From United States Light-house Board, Washington, D. C.:

Annual Report for fiscal year ending June 30, 1879.

From United States Naval Observatory, Washington, D. C.:

Catalogue of the United States Naval Observatory. Part 1. Astronomical Bibliography. Prof. Edward S. Holden. Washinton, 1879.

From Gen. G. K. Warren, Newport, R. I.:

Report upon Bridging the Navigable Waters of the United States, being Appendix X of the Annual Report of the Chief of Engineers for 1879. Gen. G. K. Warren. Washington, 1879. (2 copies.)

From W. W. Wilson, Yonkers, N. Y.:

Seventh Annual Report of the Board of Water Commissionors of the City of Yonkers, N. Y. (3 copies.)

From Gen. Horatio G. Wright, Chief of Engineers, U. S. A., Washington, D. C:

Official Army Register for January, 1880.

The Improvement of the Allegheny River, Pennsylvania. Col. Wm. E. Merrill. (2 copies.)

Information in regard to the Appropriation for the Improvement of the Allegheny River, from Pittsburg to the mouth of French Creek. Col. Wm. E. Merrill.

Report in relation to the survey of the Arkansas River, near Pine Bluff, with estimates of cost of improving the same. Maj. C. R. Suter. (2 copies.)

A report of a survey with a view to the construction of a ship canal to connect the waters of Delaware and Chesapeake Bays. Maj. W. P. Craighill. (2 copies.)

Report of survey of Delaware River at Chester and Marcus Hook, Pa., with accompanying recommendations touching the construction of an ice-harbor at that point. Col. J. N. Macomb. (2 copies.)

Improvement of Rocky River Harbor, Ohio. Maj. J. M Wilson. (2 copies.)

Papers relative to the payment of first installment of compensation to Mr. James B. Eads, for maintenance of channel at South Pass, Mississippi River, for quarter ending October 30, 1879.

Report relative to the improvement in Harlem River, New York, and making certain recommendations. Gen. John Newton. (2 copies.)

Copy of letter inclosing draft of proposed act for the operation, maintenance and repair of locks and dams on Great Kanawka River. Maj. W. P. Craighill. (2 copies.)

Report in regard to the superintendence, &c., of the Louisville and Portland Canal. Gen. G. Weitzel. (2 copies.)

Senate resolution of January 7, 1880, regarding the condition of the Missouri River, between Omaha and Plattsn outh, Neb., and inclosing a report on same from the Chief of Engineers. (2 copies.)

Report of surveys of the Mississippi River at Hannibal, Mo., and memorial of the City Council, with accompanying reports. Capt. A. Mackenzie. (2 copies.)

Correspondence in relation to the construction of a bridge across the Ohio River at Beaver, Pa., by the Pittsburg and Lake Erie Railroad Company. Col. Wm. E. Merrill. (2 copies.)

Report of survey of Pataluma Creek, California. Col. Geo. H. Mendell. (2 copies.)

The improvement of the harbor at Petersburg, Va. Maj. W. P. Craighill. (2 copies.)

Senate resolution, December 3, 1879, relating to improvement of Taunton River, Mass., with estimates of cost of same. Gen. G. K. Warren. (2 copies.)

Report of a resurvey of the outlet to Wolf Lake, Indiana. Capt. G. J. Lydecker. (2 copies.)

Report of the Surveyor-General of Wyoming for the year 1879. Edward C. David.

From other sources:

Annual report of Railroad Commissioners of Massachusetts for 1879.

The Library Journal. Vol. V., Nos. 1 and 2.

Zweite Abhandlung über die Wasserzunachme in den Quellen, Flussen und Strömen bei Steigerung der Hochwasser in den Culturländern. Gustav Ritter von Wex. Vienna, 1079.

ANNOUNCEMENTS.

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Sessions for the consideration of professional subjects, and one for the transaction of business, will be held.

The details of the programme will be announced as soon as determined by the local committee.

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LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

	Date of Election.
ANDERSON, THOMAS S.....Chief Engineer, Board Mississippi River Commission, Greenville, Miss.	March 3, 1880.
FIELD, GEORGE S.....Manager Central Bridge Co., 52 Wall Street, New York.....	April 7, 1880.
GREENWOOD, WILLIAM H..Civil Engineer, Cañon City, Colorado....	March 3, 1880.
HEUER, WILLIAM H.....Captain of Engineers, U. S. A., 37 Union St., New Orleans, La.....	March 3, 1880.
MEIER, EDWARD D.....Meier Iron Co., St. Louis, Mo.....	February 4, 1880.
NEILSON, CHARLES.....Engineer in charge Fuel Department, N. Y. L. E. & W. RR., New York..	January 7, 1880.
WAITE, CHRISTOPHER C....Chief Engineer and Superintendent Muskingum Valley RR., Zanesville, O.....	March 3, 1880.

ASSOCIATE.

PUTNAM, JOSEPH W.....Sup't Bridges New Orleans and Mobile Railroad, Box 2734, New Orleans, La..	March 3, 1880.

CHANGES AND CORRECTIONS.

MEMBERS.

ANDERSON, ADNA.... ....Engineer-in-Chief, Northern Pacific Railroad, St. Paul, Minn.

BURR, JAMES D.....Ass't Engineer, P. and A. V. and N. M. and S. P. R.R., Topeka, Kansas.

COGSWELL, WILLIAM B.... 108 Willow St., Syracuse, N. Y.

CHANGES AND CORRECTIONS.

MEMBERS.

EARLY, JOHN E.....Division Engineer, Atchison, Topeka and Santa Fé Railroad, Pueblo, Colorado.

KATTE, WALTER.....Chief Engineer, New York Elevated Railroad, 7 Broadway, New York City, N. Y.

KINSLEY, THOMAS P.....Sup't National Construction Co., East Long Branch, N.J.

MONROE, J. ALBERT.....Providence, R. I.

SEDGWICK, THOMAS S.....Assistant U. S. Engineer, Galveston, Texas.

ASSOCIATE.

WHEATON, EDWARD.....Westfield, Clark Co., Ill.

DEATH.

ST. JOHN, ISAAC MUNROE..Elected member, July 14, 1871. Died April 7, 1880.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VI.—May, 1880.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

April 21st, 1880.—The Society met at 8 P. M. Vice-President Chanute in the chair.

The death of I. M. St. John, Member A. S. C. E., was announced, and the appointment of a committee to prepare a memoir for publication was directed.

Arrangements for the approaching Convention were read.

Notes of experiments upon the relative efficiency of gas and the electric light were presented by George W. Dresser, and discussed by members present.

May 5th, 1880.—The Society met 8 P. M. Vice-President Chanute in the chair.

Ballots for admission to membership were canvassed, and the following candidates declared elected: As Members—Daniel McN. Currie, of St. Louis, Mo.; Joseph Tintorer Giberga, of Barcelona, Spain; Thomas Jackson, of Fort Wayne, Ind.; James MacNaughton, of Albany, N. Y.; George W. McNulty, of Brooklyn, N. Y.; Albert A. Robinson, of Pueblo, Col.; Charles G. Weir, of New York City, N. Y.; Samuel H. Yonge, of St. Charles, Mo. As Associates—George C. W. Belcher, of St. Louis, Mo.; William H. Burr (elected Junior, June 3, 1874), of Troy, N. Y.

The Committee on reception of M. de Lesseps, and the engineers accompanying him, made a final report.

The following resolution was adopted:

That for the present the Society rooms be open on each Wednesday evening instead of Thursday evening as heretofore, and that during the cool weather the rooms be also opened each Saturday evening.

OF THE BOARD OF DIRECTION.

MARCH 11TH, 1880.—Applications were considered. Communications in reference to the Committees on Preservation of Timber and on Testing of Cements were acted upon.

APRIL 5TH, 1880.—Applications were considered. Action was taken as to a continuance of the lease of the Society House. The Secretary was instructed to notify members in arrears for dues, and request payment. The programme for the Twelfth Annual Convention was considered.

APRIL 7TH, 1880.—Applications were considered.

MAY 6TH, 1880.—Applications were considered. Appropriations were made. Action as to dues from members in arrears was directed.

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ADDITIONS.

MEMBERS.

Date of Election.

BLUNDEN, HENRY D.....(Elected Junior, January 5th, 1876), Ass't Engineer N. Y., L. E. and W. RR., 187 West St., New York City, N. Y..... February 4, 1880.

JOHNSON, LORENZO M.....(Elected Junior, March 3d, 1875), General Manager Cairo and St. Louis RR., 520 Walnut St., St. Louis. Mo.....April 7, 1880.

KNIGHT, WILLIAM B.....(Elected Junior, January 6th, 1875), P. O. Box L., Kansas City, Mo. January 7, 1880.

SEYMOUR, HORATIO, Jr.....(Elected Associate, January 8th, 1873), State Engineer, and Surveyor, Albany, N. Y.....April 7, 1880.

SHAILER, ROBERT A.....Assistant Engineer Edgmoor Iron Iron Co., Wilmington, Del.....March 3, 1880.

JUNIOR.

PEGRAM, GEORGE H.....213 Washington Ave., St. Louis, Mo. April 7, 1880.

CHANGES AND CORRECTIONS.

MEMBERS.

BLAISDELL, ANTHONY H....Western Boat Building Co., South St. Louis, Mo.

DRESSER, GEORGE W.....35 University Place, New York City, N. Y.

EMERY, CHARLES E.....16 Cortlandt St., New York City, N. Y.

GOLAY, PHILIP.....Paducah, Ky.

GRANT, WILLIAM H.....71 Broadway, Room 88, New York City, N. Y.

HARRIS, ROBERT L.....Austin, Texas.

HEMBULE, EDWARD.....Engineer, Delaware Bridge Company, Major Block, Chicago, Ill.

HERSCHEL, CLEMENS.....Hydraulic Engineer, Holyoke Water Power Company, Holyoke, Mass.

MORRIS, MARSHALL.....Engineer and Superintendent Road Dep't, L. N. A. and C. RR., Louisville, Ky.

NEWMAN, ROBERT M.....Lansing, Mich.

NICHOLSON, GEORGE B.....Division Engineer, Cin., South. RR., 134 Vine St., Cincinnati, Ohio.

WHITFORD, OSCAR F.....Jamestown, Boulder Co., Colorado.

JUNIOR.

CLARK, IRA E.....Davisville, Yolo Co., Cal.

STAATS, ROBERT P.....N. Y., L. E. and W. RR., office 187 West St., New York City, N. Y.

FELLOW.

NORTON, FREDERICK O....45 Coal and Iron Exchange, New York City, N. Y.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VI.—June, 1880.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

TWELFTH ANNUAL CONVENTION OF THE SOCIETY.

Held at St. Louis, Mo., May 25, 26, 28, 1880.

May 25th.—The Twelfth Annual Convention was held in the City of St. Louis, in the Hall of the Washington University. The Convention was called to order on Tuesday, May 25, 1880, at 10 A. M., by John Bogart, Secretary of the Society. The chair was taken temporarily by Vice-President James B. Francis.

On the nomination of the local committee, James B. Eads, of St. Louis, was elected Chairman of the Convention. William P. Shinn, of St. Louis, was elected Vice-Chairman.

On taking the chair, Mr. Eads said: Gentlemen of the Convention, I feel profoundly grateful for this evidence of your regard. To be called upon to preside over the deliberations of the Society of Civil Engineers, numbering, as it does, among its members many of the most eminent engineers in the world, men whose originality of conception, boldness

of design and high scientific attainments have added so much lustre to the profession at home and abroad, should certainly fill the ambition of any member of the Society. I, therefore, repeat to you, that I feel deeply sensible of the high honor which you have conferred upon me. As the profession of a civil engineer does not involve a knowledge of parliamentary rules, I shall have to ask your forbearance if I commit any errors in that particular, and as engineers are not expected to be orators, I shall proceed at once to the order of business. We have an orator present who will address the Convention, the Hon. Henry Overstolz, Mayor of St. Louis. I will appoint Col. J. B. Moulton and Mr. L. M. Johnson to escort Mayor Overstolz to the platform.

As Mayor Overstolz came upon the platform, the Chairman said: I take special pleasure in introducing my personal friend, the Hon. Henry Overstolz, whose statesmanship, good judgment and careful administration of our city affairs have done so much to advance the prosperity of our city.

Mayor Overstolz said: Mr. President and Gentlemen of the Convention, Captain Eads, in his short address, has paid me a compliment which I think you will say I do not deserve, the compliment of being an orator. It is one of my weaknesses that I cannot make public speeches. I have, therefore, written my address, and I will read it.

Mayor Overstolz then read the following address:

ADDRESS OF WELCOME BY MAYOR OVERSTOLZ.

Mr. President and Gentlemen of the Convention: The government and people of the City of St. Louis most cordially welcome you on this occasion, and gladly extend to you the freedom and hospitality of the city. This is, I believe, the Twelfth Annual Convention of the American Society of Civil Engineers, and while we trust that its results may be equal in harmony and importance with any of the former meetings, we further hope that you may carry away from St. Louis some adequate impression of its commercial wealth and influence, and of the warm sympathetic interest with which all of our people regard the objects and spirit of your Society.

Gentlemen, you meet to-day in the great inland city of the continent. One whose history and development, and that of the magnificent regions surrounding it, constitute one of the most marvelous chapters in the record of American civilization. Within the space of almost half a century a mighty people and a metropolis, the commercial influence of which is felt throughout the globe, have been created. The time is not yet beyond the memory of living men when St. Louis was but a river village, and the Valley of the Mississippi was almost in a state of nature. This swift transformation scene, this "miracle-play" of history is full of solemn significance and beauty, but chiefly does it illustrate the irre-

sistable power of human energy when guided by the improved instruments and principles of modern knowledge.

I allude to these things, gentlemen, not from any spirit of enthusiasm for the city of my home, but because there are facts connected with the rapid advance of St. Louis that have educated our people to appreciate properly, and to respect profoundly, the glorious profession of which this Convention is at once the exponent and representative. The natural advantages of location, the settlement and cultivation of the vast agricultural lands stretching out on all sides of us might ultimately have made St. Louis an important city, but only by a slow process, stretching through many ages. In the olden times, in the gray and flickering dawn of civilization, cities and their commercial influence were slow of growth, and progress could only be accelerated by making them the seat of imperial power. It is only in modern times that it became possible to compress civic growth within the limits of a century or less.

This possibility is almost wholly the product and fruit of the science of civil engineering, and to this science the rapid progress of St. Louis must be largely attributed. It was the steamboat that first stimulated into activity the sluggish life of the river trading post; it was the railroad that broke down the barriers of distance, and, pouring in population and wealth, started our foundries and factories, and carried the products of our industries to the shores of the Eastern and Western oceans, and it was the telegraph that made the daily diffusion of our commercial data possible, and so rendered possible the establishment of a controlling Western market here. Improvements in machinery stimulated all branches of manufacture; the building of our magnificent bridge made a railroad highway across the Mississippi and gave us indispensable commercial facilities; and lastly, the jetties have brushed away the obstructions at the mouth of the Mississippi, and made a broad and deep highway to the ocean for the ships that carry our cereals to all quarters of the world.

These things, these great achievements, are the work of civil engineering, and of sciences connected therewith. It is the men of this profession that practically apply science to the forwarding of human industry, and this profession has undoubtedly accomplished more for the material advancement of this country than any I know of.

The facts alluded to have taught the citizens of St. Louis the benefits flowing from this profession. They realize all it has done for the city in its trade, manufactures, waterworks, and general improvements. Hence, it is evident, gentlemen, you are among friends and admirers, and this feeling should assist the enjoyment of your visit.

The President of our Board of Improvement and the Chief Engineer of our Waterworks are, I believe, members of your Society, also our distinguished citizen, James B. Eads, whose bold and original genius

has done so much for this city, in the great steel arch bridge over our river, and for the country generally, in the successful execution of the jetties. To a former member of your Society, the late Mr. Kirkwood, this city is indebted for the original design of our Waterworks system.

In a city that owes so much to civil engineers, there must be many objects worthy the attention and inspection of the members of this Convention. The bridge, the waterworks, the iron furnaces, and many other features of interest will, I think, prove worthy of a visit. I trust you will also have time to see our parks and public institutions, and so far as possible, I will gladly co-operate in any arrangement for your entertainment.

In welcoming this Convention, I express the sentiments of all our people, and I beg to assure you that your proceedings will be regarded with the deepest interest and respect by all classes.

The following members and guests were in attendance at the Convention :

Members of the Society—E. R. Andrews, New York; Wm. S. Auchincloss, Philadelphia; Theodore Allen, St. Louis; James P. Allen, Rock Island, Ill.; John B. Atkinson, Earlington, Ky.; E. W. Bowditch, Fred'k Brooks, Boston; H. Bissell, Salem, Mass.; John W. Bacon, Danbury, Conn.; H. D. Blunden, John Bogart, New York; Charles B. Brush, Hoboken, N. J.; Charles E. Billin, Robert Briggs, Philadelphia. Arthur Beardsley, Swarthmore, Pa.; G. Bouscaren, Cincinnati; A. H. Blaisdell, St. Louis ; Edward Baumann, Chicago ; James D. Burr, Topeka, Kansas; O. E. Cushing, Lowell, Mass.; Theodore Cooper, J. James R. Croes, New York; Wm. B. Cogswell, Syracuse, N. Y.; Martin Coryell, Lambertville, N. J.; D. N. Currie, A. J. Chaphe, St. Louis; E. S. Chesbrough, Chicago; J. H. Cunningham, Milwaukee; Charles G. Darrach, Philadelphia; Alexander Dempster, Pittsburgh; Edwin A. Doane, Meadville, Pa.; M. M. Defrees, Indianapolis; James Dun, James B. Eads, St. Louis; Geo. D. Emerson, Rolla, Mo.; James B. Francis, Lowell, Mass.; Clark Fisher, Trenton, N. J.; C. G. Force, Jr., Cleveland, O.; Henry Flad, St. Louis; B. Godwin, New York; Frederick Graff, Philadelphia; P. Golay, Cincinnati; . A V. Gude, Louisville, Ky.; Albert B. Hill, New Haven, Conn.; Wm. R. Hutton, Baltimore ; James H. Harlow, Pittsburgh; Edward Hemberle, Chicago; F. B. Howard, Detroit; B. M. Harrod, New Orleans; L. M. Johnson, St. Louis; Louis H. Knapp, Buffalo; Wm. B. Knight, Kansas City, Mo.; E. D. Leavitt, Jr., Cambridgeport, Mass.; D. Jones Lucas, Philadelphia; Thomas D. Lovett, Cincinnati; Wm. H. Lotz, Chicago; E. C. Lewis, Nashville, Tenn.; Charles Macdonald, Arthur Macy, New York; D. N. Melvin, New Springville, N. Y.; James MacNaughton, Albany; Henry G. Morris, Philadelphia; Mansfield Merriman, Bethlehem, Pa.; C. S. Maurice, Athens, Pa.; Henry G. Morse, Youngstown, O.; Robert E. McMath, E. D. Meier, Robert Moore, St. Louis; M. Meigs, Rock Island, Ill.; W.

H. McClintock, Fair Grounds, Ky.; John McLeod, Marshall Morris, Louisville; F. O. Norton, New York; George B. Nicholson, Cincinnati; Joseph O. Osgood, Milton, Mass.; E. Prince, Quincy, Ill.; George H. Pegram, St. Louis; Joseph R. Richards, Boston; Percival Roberts, Jr., Philadelphia; E. C. Rice, St. Louis; Henry B. Richardson, St. Joseph, La.; C. L. Strobel, Pittsburgh; S. Sheldon, Cleveland; Robert A. Shailer, Wm. P. Shinn, Charles A. Smith, C. Shaler Smith, St. Louis; Max E. Schmidt, Memphis, Tenn.; Marshall M. Tidd, Boston; Cook Talcott, Newark, N. J.; E. N. Kirk Talcott, Morgan Park, Ill.; John G. Van Horne, Jersey City, N. J.; Frank O. Whitney, Boston; W. H. Wiley, W. E. Worthen, New York; Charles D. Ward, Jersey City, N. J.; Ashbel Welch, Lambertville, N. J.; John Whitelaw, Cleveland; D. W. Wellman, Thomas J. Whitman, St. Louis; Don J. Whittemore, Milwaukee; George Y. Wisner, Detroit; S. Whinery, Wheeler, Ala.; Samuel H. Yonge, St. Charles, Mo.

Visiting Engineers.—J. Y. McClintock, W. Ripley Nichols, E. B. Noyes, Boston; A. F. Noyes, Newton, Mass.;* Howard Constable, Harold A. Freeman, L. C. Madeira, Howard Murphy, T. Roney Williamson, Philadelphia;† W. Marshall Rees, Memphis, Tenn.;‡ Edward Adams, Pittsburgh; J. A. Coulter, Greenburg, Pa.; F. W. Gordon, Karl Van Wagner, Pittsburgh, Pa.;§ R. Chauvenet, John W. Conlogue, Claude Freeman, Carl Gayler, James W. Hill. H. S. Hopkins, Jacob Johann, Richard Klemm, J. H. Maclind, John H. Maxon, Julius Moulton, Charles Pfeiffer, Frank H. Pond, Wm. B. Potter, A. Rauschenback, P. W. Schaumleffel, Fred. Schickle, Thad. S. Smith, A. A. Talmage, Wm. Taussig, B. Warren, Wm. Wise, C. M. Woodward, St. Louis;‖ Charles J. Bates, E. L. Bremerman, E. C. Carter, St. Louis; M. Cowles, Chicago; Howard Fleming, George H. Frost,¶ New York; John C. Gault, Allen C. Glasgow, George B. Hopkins, St. Louis; Wm. W. Jefferis, Westchester, Pa.; R. Ralston Jones,¶ Keokuk, Ia.; Thos. B. Lee, Newark, N. J.; Thos. McKissock, St. Louis; H. S. Morse, Indianapolis; J. H. Morley, C. P. Morrison, J. B. Moulton, J. A. Ockerson, St. Louis; L. S. Olmstead,¶ Jacksonville, Ill.; Hon. Henry Overstolz, St. Louis; George C. Prussing, Chicago; J. R. Rees, St. Louis; W. H. Sears, Eau Claire, Wis.; C. H. Sherman, Charles W. Stearns, A. W. Loper, St. Louis; Joseph D. Weeks, New York; John W. Weston,¶ Chicago; Wm. Woodyard, New York.

The Chairman then announced the committee on the details for the proceedings of the Convention, order of papers, discussions, etc., viz.: Henry Flad, J. J. R. Croes, and Charles Macdonald.

* Members Boston Society of Civil Engineers.

† Members Engineers' Club of Philadelphia.

‡ Member American Institute, Mining Engineers.

§ Members Engineers' Society, Western Pennsylvania.

‖ Members Engineers' Club of St. Louis.

¶ Members Civil Engineers' Club of the Northwest.

The Secretary announced the programme of excursions, invitations to points of interest, etc., as arranged by the local committee, at St. Louis.

A paper, subject, "The Hudson River Tunnel," by Arthur Spielmann and Charles B. Brush, Members, A. S. C. E., was then read by Charles B. Brush, and discussed by E. S. Chesbrough, James B. Eads, James B. Francis, Ashbel Welch, and Charles B. Brush.

A paper, subject, "Location of the Chimbote Tunnels, Peru, 1874–5," by O. F. Nichols, Member A. S. C. E., was read by J. J. R. Croes; the Convention then adjourned.

MAY 26TH.—The Convention resumed its session at 9 A. M.

A paper, subject, "Tensile Tests of Cement and an Appliance for more accurate Determinations," by D. J. Whittemore, Member A. S. C. E., was then read by the author, and discussed by M. Coryell, James B. Eads, James B. Francis, William P. Shinn, Ashbel Welch and D. J. Whittemore.

A paper, subject, "American Cements," by F. O. Norton, Fellow A. S. C. E., was then read by the Secretary, and discussed by John Bogart, E. S. Chesbrough, James B. Francis, J. H. Harlow, W. R. Hutton, Max E. Schmidt and D. J. Whittemore.

A paper, subject, "Waterproof Coverings," by F. Collingwood, Member A. S. C. E., was then read by the Secretary.

A paper, subject, "Web Strains in Simple Trusses," by E. Sweet, Jr., Member A. S. C. E., was then read by the Secretary.

A paper, subject, "On the Crippling Strength of Wrought-Iron Columns," by C. L. Gates, Junior, A. S. C. E., was read by the Secretary.

Reports of committees being called for, and that from the Committee on Tests of American Iron and Steel being in order, John Bogart, Secretary, said:

The Chairman of that committee, Gen. W. Sooy Smith, is now in Europe. As Secretary of the Society, I have sent to each member of the committee a note, saying that it would be called upon for a report at this Convention, but the Secretary has received no report, and if no member of the committee is present or has a report ready, I think proper that I should say that Gen. Smith, just before sailing, informed me that his efforts, or the efforts of the committee in regard to the continuance of the board for the testing of American Iron, Steel and other metals before Congress, had not, so far, been successful, and that there was danger that the results of so enormous amount of labor by that Committee would be lost. I think that is about what the Chairman of that committee would say if he were here, but of course it is not so forcibly presented, nor in so vigorous a manner as Gen. Smith would put the case.

William P. Shinn :—Gentlemen of the Convention, I will take this occasion, as a manufacturer of steel, to say to the members that I regard the work of this committee as one of the very greatest importance to American engineering. All of us who have had occasion to work with iron and steel know that we have been working with material about which we knew very little. If we have discovered, from time to time, various phenomena in their use and action under strain, we could not tell whether these phenomena were subject to any law, because we had not made sufficient tests to define any law. We have been endeavoring to use a material manufactured in this country from raw materials found in this country, upon formula established with regard to material manufactured in another country out of raw materials found in that country, and it needs no argument to show how absurd the effort was, and how unwise it was to expect any good results. From which I repeat, therefore, it is of the utmost importance to this Society that every member of it should use whatever influence he may have with members of Congress and the public to bring about a restoration of this board for testing American iron and steel. As far as I can see, it is only by that means that we shall arrive within any reasonable time at the laws which govern the manufacture and use of iron and steel in this country.

The Vice-Chairman called for a report of the Committee on "Gauging of Streams."

J. J. R. Croes (chairman of the committee).—"The Committee on Gauging of Streams" has no written report to make. The chairman can only state that some one hundred letters or more have been written to members of the Society in various parts of the country during the past year asking for the gauging of streams, specially for the flood water discharge of streams in places where there were reports of very heavy rains and freshets. Some ten replies have been received, but in none was there any information given.

The Vice-Chairman next called for a report from the special committee on a "Uniform System of Tests of Cements."

Mr. D. J. Whittemore (chairman of the committee).—When I was notified that I was appointed chairman of that committee, I wrote the other members of the committee and gave topics which I thought proper for us to consider in devising a uniform system of tests, but have had hardly time yet to receive their answers, and therefore am able to report only progress.

The Vice-Chairman.—I think it best to announce that all these special standing committees will be continued unless a motion is made for their discharge.

The Secretary then read the report of the Finance Committee, as follows :

The Finance Committee would respectfully report :

That on entering upon their term of office they carefully compared the accounts of the Secretary and Treasurer for the preceding year, including the books and vouchers, and found them correct and corresponding with the annual reports of those officers for that year, to which reports your committee would refer for a full and complete statement of all the receipts and expenditures, together with the assets and liabilities of the Society at the commencement of the present fiscal year.

During that portion of the present year already passed, a larger expenditure than usual has been made for printing circulars and notices, and postage on the same ; also in putting the library in better order and making catalogues of the books.

This has been done in the carrying out of those ideas which have had for their object the increasing of the usefulness and advancing the interests of the Society. The wisdom of this is already manifested by a larger increase of membership and more general interest.

The delinquency which still continues in regard to the payment of dues may well claim thoughtful attention, as by this delinquency our finances have been all along seriously embarrassed, and we have been prevented from doing many things which would have added to our prosperity. It is hoped that the dawn of better times now upon us will show that it was not a lack of interest and want of a disposition to pay that has kept so large a list of debtors upon our books.

While circumstances have in the past, and still do render it necessary to be very economical and prudent in our expenditures, we feel it our duty to congratulate the Society upon its present increasingly prosperous financial condition.

Your committee feel that it is a matter of great importance to our future prosperity that suitable permanent quarters be obtained for the Society at as early a time as they can be secured, without embarrassment to our finances, and hope the movement already inaugurated may, in its present, or some modified form, result in placing us in possession of a suitable building at an early date.

In conclusion, we would congratulate the Society upon the fact, that financially, and in every other respect, this Society is now more prosperous than at any previous time in its history.

Respectfully submitted,

W. H. Paine.

Chairman of Finance Committee.

The report was accepted and filed.

The Vice-Chairman then called for the report of the Committee on the Preservation of Timber.

B. M. Harrod (chairman of the committee).—I can only report that the committee has met, an organization has been effected, and the committee intends to continue its meetings during the sitting of the Convention. We, therefore, simply report progress.

The appointment of a Nominating Committee was then considered, and after discussion, it was determined to choose the committee from nominations made representing the resident members at New York, the Atlantic States, the Lakes and Ohio Valley, the Northwest and the Southwest.

The following members of the Society were appointed as a Nominating Committee :

Theodore Cooper, of New York; Frederick Graff, of Philadelphia; William E. Merrill, of Cincinnati; E. S. Chesbrough, of Chicago; C. Shaler Smith, of St. Louis.

The Convention then adjourned.

MAY 26TH.—The Convention met at 8 P. M.

The Annual Address prepared by O. Chanute, Vice-President of the Society, was read by the Secretary.

At the conclusion of the address, it was, on motion, resolved, that the thanks of the Convention be tendered to Vice-President Chanute.

The Convention then adjourned.

MAY 28TH.—The Convention met at 9 A. M.

A paper, subject, "Ship Canal Locks, Calculated for Operation by Steam," by Ashbel Welch, Member A. S. C. E., was read by the author.

A paper, subject, "Practical Consequences of Variation of the Wet Section of Rivers under General and Special Conditions," by Robert E. McMath, Member A. S. C. E., was read by the author.

A paper, subject, "Notes on the South Pass Jetties," by Max E. Schmidt, Member A. S. C. E., was then read by the Secretary, and additional remarks on the subject were made by James B. Eads.

A paper, subject, "Cheap Transportation *versus* Rapid Transit and Delivery," by M. Coryell, Member A. S. C. E., was then presented.

A paper, subject, "Wind Pressure against Bridges," by Ashbel Welch, Member A. S. C. E., was then read by the author, and discussed by Robert Briggs, Theodore Cooper, James B. Eads, James B. Francis and C. Shaler Smith.

On motion, it was resolved, that a committee be appointed to correspond with Gen. A. J. Myers, Chief Signal Officer, U. S. A., on the subject of experiments upon wind pressures, and Messrs. C. Shaler Smith, Theodore Cooper and Robert Briggs were appointed as such committee.

A paper, subject, "The Improvements of the Harbor of Quebec," by J. Vincent Browne, C. E., was presented by the Secretary.

Resolutions of thanks were passed to the Local Committee at St. Louis, to the members of the Engineers' Club of St. Louis, to the

NOTE.—[For the proceedings at the business meeting of the Society, see report, page 49 *seq.*]

various organizations, clubs, firms and individuals who had so largely extended courtesies to the Society, to the Western Union Telegraph Company for the use of its lines for social and domestic telegrams, and to the officers of the various railway corporations over whose lines the members had traveled *en route* to the Convention.

The Convention adjourned *sine die.*

The arrangements made by the Local Committee for excursions and visits to places of interest, and for the comfort and entertainment of the visitors to the Convention were very complete. The Local Committee was composed of members of the Society, and of the Engineers' Club of St. Louis, appointed at a joint meeting, and was as follows : Theodore Allen, A. H. Blaisdell, James B. Eads, Henry Flad, Claude Freeman, L. M. Johnson, Robert E. McMath, E. D. Meier, Robert Moore, Fred. Shickle, W. P. Shinn, C. Shaler Smith, D. W. Wellmann, Thomas J. Whitman.

These gentlemen were assisted by the other members of the Special Committees for each day.

The programme was illustrated, and handsomely printed. Its details, apart from the sessions of the Convention, are as follows:

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Twelfth Annual Convention—St. Louis, May 25, 26, 27, and 28th, 1880.

The headquarters of the Society during the Convention will be at the Lindell Hotel. The Secretary's office will be in Parlor 22.

The meetings of the Convention will be held in the Washington University, on the southwest corner of Washington avenue and Seventeenth street.

From Lindell Hotel take yellow cars on Washington avenue.

Members of the Society and guests of the Convention will please report to the Secretary's office at the hotel immediately upon arrival.

The following named railways have kindly placed special trains at the disposal of the Convention for the excursions indicated in the programme : The Missouri Pacific Railway ; the Wabash, St. Louis & Pacific Railway ; the St. Louis, Iron Mountain & Southern Railway ; the St. Louis, A. & T. H. R. R. Co. ; the E. St. L. & C. R. W. and the Union Transit Co.

The various manufacturing establishments named in the programme extend invitations to the Convention to visit and inspect their works.

The St. Louis Club also extends its hospitalities to members of the Convention.

Special committees for each day are designated in the programme, and will be recognized by red rosettes.

Members of the Society, and guests of the Convention, will be provided with special badges.

Tuesday, May 25th.—The Convention will assemble at the Washington

University at 9:30 A. M. ; adjourn at 12 M. ; lunch at hotel ; leave Union Depot at 1:30, by Wabash, St. Louis & Pacific Railway, and arrive at St. Charles at 2:15 P. M. ; inspect St. Charles Bridge ; leave St. Charles at 2:45 P. M., and return by steamboat ; arrive at the St. Louis Water Works at 5:45 P. M. ; leave Water Works at 6:30 and land at the Bridge at 7 P. M.

Special Committee for the day.—C. Shaler Smith, John C. Gault, Thos. J. Whitman, A. J. Chaphe, Thos. McKissock.

Wednesday, May 26th, St. Louis Engineers' Club Day.—At 1 P. M. take steamer *Elon G. Smith*, at foot of Washington avenue ; lunch on the boat ; arrive at Vulcan Steel Works at 2 P. M. ; visit Vulcan Steel Works, Western Iron Boat Building Co., Jupiter Furnace and Missouri Zinc Works until 3:45; at this point the excursion will divide into two parties : party No. 1 will take Missouri Pacific Railroad at 3:45 and go *via* Kirkwood to Cheltenham, arriving at 4:45 : there visit St. Louis Smelting Works and Laclede Fire Brick Works and leave at 5:45, arriving at Union Depot at 6 P. M.

Special Committee.—Fred. Shickle, J. H. Maxon, A. A. Talmage.

Party No. 2 will leave the Zinc Works at 3:45 and cross the river on the steamer *Elon G. Smith* to the Meier Iron Works ; at 4:30 leave Meier Iron Works by East St. Louis & Carondelet Railway, and go to National Stock Yards.

Special Committee.—B. Warren, Chas. Pfeiffer, Wm. Taussig, Claude Freeman, Jno. W. Conlogue.

Thursday, May 27th.—Excursion to Iron Mountain, Pilot Knob and Crystal City. Leave Levee and Washington avenue at 7:30 A. M. on the St. Louis, Iron Mountain & Southern Railway ; arrive at Iron Mountain at 10:45 A. M. ; leave Iron Mountain at 11:45 A. M. ; visit Pilot Knob 12 to 1:20 P. M.; arrive at Arcadia at 1:30 P. M. Dinner. Leave Arcadia at 2:10 P. M.; arrive at Crystal City at 4:30 P. M.; leave Crystal City at 6 P. M.; arrive at Washington avenue at 7:30 P. M.

Special Committee.—E. D. Meier, A. W. Soper, L. M. Johnson, W. P. Shinn, J. H. Morley.

Friday, May 28th.—In the afternoon, carriages will be at the disposal of members to visit such places as they may desire, such as Shaw's Garden, Fair Grounds, Merchants' Exchange, Cotton Compress Works, American Wine Co.'s Cellars, National Stone Block Co.'s Works, Wood Preserving Works, &c., &c.

Special Committee.—Chas. A. Smith, Theodore Allen, A. H. Blaisdell.

Subscription Dinner at Masonic Hall at 7:30 P. M.

The Committee in charge of the Carriage Excursion of Friday the 28th, would suggest to such members and invited guests of the Society as have no individual preferences, that visits may be made to the places named below by parties as follows :

No. 1.—Excursion by steamer *A. A. Humphreys*, through the kindness of Capt. Oswald H. Ernst, U. S. Engineers, at 2:30 (not 3h P. M.), from near the foot of Washington avenue, to the Horsetail Dyke, where may be seen the latest practice in the improvement of Silt Bearing Rivers.

Committee.—Capt. O. H. Ernst, D. M. Currie.

No. 2.—Carriage Excursion at 2h 30m P. M., to Pipe Foundry and general

iron works of Shickle, Harrison & Co., The Harrison Wire Works, Lafayette Park, Compton Hill Reservoir, Shaw's Garden, Western (W. J. Lemp's) Brewery.

Committee.—Chas. A. Smith, M. L. Holman.

No. 3.—Carriage Excursion at 2h 30m to the Levee, inspecting one or more Typical Western River Steamboats, Peper and St. Louis Cotton Compress Companies, The St. Louis Cotton Mill, Anheuser Busch Brewery.

Committee.—Theodore Allen, J. W. Meier.

No. 4.—Carriage Excursion at 2h 30m to The St. Louis Lead & Oil Works, The Works for the Preservation of Timber, The Laclede Rolling Mill, The St. Louis Fair Grounds, The American Wine Co.

Committee.—A. H. Blaisdell, P. W. Schaumleffel.

Persons desiring to go to places other than above, please inform the Committee for Friday.

A pamphlet, with descriptions of matters of engineering interest, the parks, public works, &c. of the city, together with a map, was prepared and presented to the Convention.

Special facilities were provided by the officers of the St. Louis Bridge for an examination of that work by visitors to the Convention during their stay in St. Louis.

On Saturday, May 29th, a number of those who had attended the Convention, left St. Louis and proceeded *via* Kansas City to Plattsmouth, Neb., by invitation of Geo. S. Morison, Member of the Society, who is erecting at that point a bridge over the Missouri river. Opportunity was afforded for a full examination of this structure, one span of which, 400 feet in length, had just been erected.

Both in going to the Convention, on the trip to Plattsmouth and Omaha, and on the return to their homes, the attendants upon the Convention were afforded by the railway companies special accommodations in travelling, and also were given opportunities for examining the works of engineering interest on the various lines. These courtesies were so extended that a general acknowledgement of them, as expressing the hearty appreciation by the Society of these attentions, seems more appropriate than to attempt to publish a detailed list of all those from whom such attentions were received.

MINUTES OF MEETINGS OF THE SOCIETY.

May 19th, 1880.—The Society met at 8 P. M. John C. Campbell in the chair. A paper by T. S. Sedgwick, Member of the Society, subject: "Suggestions and Notes in regard to a New Decimal System of Weights and Measures," was read by the Secretary, and discussed by Messrs. Collingwood, J. C. Campbell, Emery, Forney and Yardley.

MAY 26TH, 1880.—[*Meeting of the Society held during the 12th Annual Convention at St. Louis.*] The Society met at 9:30 P. M. Vice-President James B. Francis in the chair.

The Secretary, in accordance with the direction of the last Annual Meeting, presented for discussion the following suggestions made in the last report of the Board of Direction :

"It has been suggested by a number of members, that the date of the Annual Meeting is particularly inconvenient, coming, as it does, the day after the date of the elections in quite a number of States. The Secretary has been informed by several members that their attendance at that day would be inconvenient, and, in some cases, impracticable, and a change in the date of the Annual Meeting might be discussed, and a more desirable day suggested.

The Board suggests that the fiscal year shall end on December 31st ; that the Annual Meeting, election of officers and reception of reports be held on the 3d Wednesday of January, and that the term of office should begin on the day of election.

These suggestions were discussed.

The death of Thomas S. Hardee, Member A. S. C. E., of New Orleans, La., which occurred May 21st, 1880, was announced, and Messrs. B. M. Harrod, B. H. Greene and Henry B. Richardson were appointed a committee to prepare a memoir for publication in the Proceedings.

The death of Max Hjortsberg, Member A. S. C. E., of Chicago, Ill. which occurred May 16th, 1880, was announced, and Messrs. W. Kattè, E. S. Chesbrough, T. C. Clarke and Willard S. Pope were appointed a committee to prepare a memoir for publication in the Proceedings.

The provisions of the Constitution and By-Laws regarding nominations, balloting and elections to membership in the Society, were discussed by William P. Shinn, C. Shaler Smith, and J. J. R. Croes.

The following preamble and resolution were offered by Charles Macdonald :

Whereas, It is contrary to the spirit of a Republican form of Government to constitute and educate at the public expense, a privileged class of engineers in military service, to whom alone are entrusted the design and supervision of works of public improvements, to the exclusion and prejudice of engineers in the civil service, whose education has not been a tax on the public treasury, who have proved themselves perfectly competent to execute works of the greatest magnitude in the best and most economical manner ; and

Whereas, The United States has adopted a policy of entrusting the design and execution of works constructed at the expense and for the benefit of the general public to engineers of the United States army ; therefore, be it

Resolved, That we hereby make an earnest protest against the injustice thus being done to us as members of a profession upon whom so largely depends the material progress of our country ; further, that a committee of seven members of this Society be appointed, with power to act in the premises, whose duty it shall be to memorialize Congress for the correction of this great wrong.

After discussion by Charles Macdonald, J. J. R. Croes, Theodore Allen, James B. Eads, E. S. Chesbrough, Theodore Cooper and Alexander Dempster, the following substitute was offered by J. J. R. Croes :

Resolved, That a committee of seven be appointed to prepare a memorial to Congress asking that Civil Engineers may be placed in full charge of the works of public improvement carried on at Government expense ; such memorial to be submitted to the Society and voted on by letter ballot, on the first Wednesday in November.

This substitute was accepted by Charles Macdonald, the mover of the original resolution.

After discussion by Theodore Allen, J. J. R. Croes, Charles Macdonald, James B. Eads, Robert Moore, William R. Hutton, John Bogart, John Whitelaw, C. Shaler Smith, and E. S. Chesbrough, the resolution was adopted.

Under the provisions of this resolution, the following committee was appointed : Charles Macdonald, J. J. R. Croes, Albert Fink, Thomas C. Clarke, Alexander Dempster, Henry Flad, Julius E. Hilgard.

Suggestions as to the place for the next (13th) Annual Convention, were made by various members, as follows : St. Paul, Minn. ; Milwaukee, Wis. ; Washington, D. C. ; Richmond, Va.

June 2d, 1880.—The Society met at 8 p. m. Joseph P. Davis in the chair. Ballots were canvassed, and the following candidates declared elected : As Members—William M. Hughes, of Cincinnati, O., Charles Kellogg, of Athens, Pa. ; Henry Manley, of Boston, Mass. As Associate—Edward Baumann, of Chicago, Ill. As Juniors—Benjamin L. Crosby, of Plattsmouth, Neb. ; William Renschel, of Cleveland, O.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Administration des Ponts et Chaussees, Paris:

List of Members for 1880.

Annals. February and March, 1880.

From American Chemical Society, P. Cassamajor, Secretary, New York:

Journal of the Society. Vol. 1. No. 12.

From American Institute of Mining Engineers, Dr. Thomas M. Drown, Secretary, Easton, Pa.:

Proceedings of the Annual Meeting held in New York. February, 1880.

Blast Furnace Working. Julian Kennedy.

Notes on Battery and Copper-Plate Amalgamation. Robert H. Richards.

Notes on the Blast Furnace. J. M. Hartman.

The Successful Manufacturer of Pressed Fuel at Port Richmond. Philadelphia, Pa. E. F. Loiseau.

The Claiborne Group and its remarkable fossils. Prof. P. H. Mell, Jr.

The Heat of the Comstock Lode. J. A. Church.

The North Staffordshire Coal and Iron District. Wm. H. Merritt.

The Mineral Resources of Southwestern Virginia. C. R. Boyd.

The Puddling Process—Past and Present. Percival Roberts, Jr.

Notes on the Siemens Direct Process. A. L. Holley, LL.D.

From American Iron and Steel Association. James M. Swank, Secretary-Philadelphia, Pa.:

Directory to the Iron and Steel Works of the United States. Corrected to March 15, 1880.

From Argentine Scienttfic Society, Don Edwardo Aguirre, Buenos Ayres:

Anales. February, 1880.

From Wm. S. Barbour, Cambridge, Mass.:

Mayor's Address and Annual Reports made to the City and Council of Cambridge for 1879.

Annual Report of the City Engineer of Cambridge, for year ending Nov. 30, 1879.

Fifteenth Annual Report of the Cambridge Water Board, for 1879.

The petition of the Mayor of Cambridge for Annexation of a part of Belmont. Hearing before the Committee on Towns.

From Boston Public Library, Mellen Chamberlain. Librarian Boston:

Bulletin for April, 1880.

From Boston Society of Civil Engineers, George S. Rice, Secretary, Boston:

Proceedings. March, 1880.

Main Drainage Works at Boston. Eliot C. Clarke.

From Bureau of Education, Washington, D. C.:

Circulars of Information of the Bureau. Nov. 1, 1880. College Libraries as aids to instruction.

From Wm. H. Burr, Troy, N. Y.:

Papers read before the Pi Eta Scientific Society. Rensselaer Polytechnic Institute. 1879-80.

From Hon. Allan Campbell, Commissioner Department Public Works, New York:

Report of the Department for Quarter ending Dec. 31, 1879. A review for the year 1879.

From Francis Collingwood, New York:

Photograph view of Two Arches next in rear of Anchorage, New York Approach East River Bridge, 33′ and 34′ span. Keystone 8′ high. Extreme height of masonry, 74′ above ground. Built, 1878.

View down Frankfort Street from Elevated R. R. Height nearest cap, 62′. Size of cap, 16′ × 5′ 2″. Built, 1878 to 1880.

Cliff Street Arch, New York approach East River Bridge. Span, 51′.8″. Clear height, 42′. Built, 1879.

Photograph one-half of one of the abutments at Vandewater Street, showing lightning Arches. Built, 1879. New York approach East River Bridge.

Photograph Skew-Arch on CherryStreet front, and view through one of the anchorage tunnels. Built, 1878. New York approach East River Bridge.

Photograph showiug Band of Brick Work in Arches, &c. New York approach East River Bridge.

From George W. Dresser, Editor, American Gas-Light Journal, New York:

Report of Proceedings of the Annual Meeting of the American Gas-Light Association.held at Cincinnati, Oct. 17, 1877, and at New York City, Oct. 15, 1878.

From Capt. James B. Eads, St. Louis, Mo.:

Address of Mr. James B. Eads before the House Select Committee on Inter-Oceanic Canals, March 9, 1880, in reply to Count F. de Lesseps.

From Albert H. Emery, New York:

Message from the President of the United States transmitting papers in the case of A. H. Emery.

From Engineers' Society of Western Pennsylvania, James H. Harlow, Secretary, Pittsburgh, Pa.:

The Alleghany River. Thomas P. Roberts.

The Metric System. William Kent.

The Tay Bridge. A. Gottlieb.

From James T. Gardner, Albany, N. Y.:
Special report of New York Survey on the Preservation of the Sceneryof Niagara Falls, and Fourth Annual Report on the Triangulation of the State. James T, Gardner, Albany, 1880.

From Charles O. Gleim, Cologne, Germany:
Zeitschrift für Bankunde. Parts I, II, III and IV. 1879.

From Samuel M. Gray, Providence, R. I.:
Annual Report of the City Engineer of Providence.
Fourth Annual Report of the Board of Water Commissioners of the City of Providence.

From Wm. Ham Hall, San Francisco, Cal.:
Report of the State Engineer of California for 1879. Wm. H. Hall.

From Institution of Civil Engineers, James Forest, Secretary, London:
The Thames Steam Ferry between Wapping and Rotherhithe. Frederic E. Duckham.
Tunnel Outlets from Storage Reservoirs. Charles J. Wood.

From Institution of Mechanical Engineers, Walter R. Browne, Secretary, London:
Transactions. January, 1880.

From David Kirkaldy, London:
Letter from David Kirkaldy to the Members of the Research Committee of the Institution of Mechanical Engineers. January 28, 1880. (Copies for distribution.)
Letter from David Kirkaldy to the President, Council and Members of the Institution of Mechanical Engineers. April 8, 1880. (Copies for distribution.)

From Louis H. Knapp, Buffalo, N. Y. :
Map showing Territory to be drained by the Ferry and Bird Ave. Receiving Sewer. Buffalo, N. Y.:

From Massachusetts Institute of Technology, Boston:
Fifteenth Annual Catalogue of the Institute. 1879-80.

From Midland Institute, Mining, Civil and Mechanical Engineers, Barnsley, England:
Transactions. December, 1879. February and March. 1880.

From Prof. Mansfield Merriman, Bethlehem, Pa.:
Register of the Lehigh University for 1879-80.

From Minister of Public Instruction, Paris:
Catalogue of the Ministry of Public Instruction. Universal Exposition at Paris, 1878. Parts 1, 2 and 3. (French.)
Part 1. Catalogue of Library of Corps of Instructors.
Part 2. Section 1. Theses. Publications of the Ministry. Subscriptions. Academic Library. Books and Archives.
Part 2. Section II. Scientific Voyages and Missions. Exhibits as to Theatrical Representation.
Part 3. Section I. Advanced Education.
Part 3. Section II. Elementary Education.
Belgian Section. Paris Exposition, 1878. Official Catalogue of the Works of Art and Products of Industry and Agriculture. (French.)

From Prof. W. Ripley Nichols, Boston :
Sanitary condiiion of Schoolhouses. Boston, Mass. Prof. W. Ripley Nichols.

From North of England Institute Mining and Mechanical Engineers, Theo. Wood Bunning, Secretary, Newcastle-on-Tyne, England;
Transactions. November and Decemher, 1879.

From Charles Paine, Gen. Sup't L. S. and M. S. R. R., Cleveland, Ohio:
Twelfth Annual Report, Cleveland, Columbus, Cincinnati and Indianapolis Railway Company. Cleveland, 1880.
Tenth Annual Report Lake Shore and Michigan Southern Railroad. Cleveland, 1880.
Annual Report Minneapolis and St. Louis Railway Company. Minneapolis, 1880.

From Steven C. Pierson, W. Meriden, Conn.:
Annual Reports of the several departments of the City of Meriden, for the years 1878 and 1879.
Second Annual Report of the State Board of Health of Massachusetts for the fiscal year ending November 30, 1878.

From Ernest Pontzen, Paris:
Les Chemins de fer devant le Parlement. L'exploitation par l'état et par l'industrié privée. M. Emile Level. Paris, 1880.
Die Alternativ-Trassen der Arlbug-Bahn. Wilhelm von Nordling. Vienna, 1879.

From Publishers Revue Generale des Chemins de fer, Edgar Monjean, Secretary, Paris:
Revue Generale des Chemins de fu. January, 1880.

From Moncure Robinson, Philadelphia, Pa.:
Obituary Notice of Mitchel Chevalier. Moncure Robinson.

From School of Mines, Columbia College, New York:
School of Mines Quarterly. Vol. I., No. 4. May, 1880.

From Sidney F. Shelbourne, New York:
A Comparative View of the Panama and San Blas Routes for an Interoceanic Canal. S. F. Shelbourne. (4 copies.]
San Blas Route, Interoceanic Ship Canal. S. F. Shelbourne. (3 copies.)

From Société des Ingenieurs Civils. M. Mallet, Secretary, Paris:
Memoirs. January and February, 1880.

From Spielmann and Brush, Hoboken, N. J.:
Scientific American and *Supplement* of May 8, 1889. Containing an account of the Progress of Work on Hudson River Tunnel.

From United States Association of Charcoal Iron Workers, John Birkinbine, Secretary, Harrisburg, Pa.:
Journal of the Association, No. 1, April, 1880.

From United States Naval Observatory, Washington, D. C.:
A Subject-Index to the Publications of the U. S. Naval Observatory, 1845-1875. Edward S. Holden.

From Gen. Horatio G. Wright, Chief of Engineers, Washington, D. C.:

Annual Report on the Improvement of the South Pass of Mississippi River, June 30, 1879. Capt. M. R. Browne. (Copies for distribution.)

Report of Survey of Mouth of Red River, La., with maps. Maj. W. H. H. Benyaurd. (2 copies.)

Report of Survey of Mississippi River, near Lake Concordia, La., and Cowpen Bend, Miss., looking to the protection of the harbors of Natchez and Vidalia. Maj. W. H. H. Benyaurd. (2 copies.)

Letter from Chief of Engineers covering copy of report from Maj. S. M. Mansfield, of the result of a re-survey of Trinity River, Tex., from its mouth to the bridge of the Great Northern Railroad, made in accordance with the River and Harbor Act of March 3, 1879. (2 copies.)

Letter from the Chief of Engineers in relation to the bills now before Congress to confirm the survey of the Pueblo of San Francisco, suggesting certain amendments. (2 copies.)

Report in regard to the Improvement of Sandusky River, below Fremont, Ohio, giving estimate of cost of same. Maj. J. M. Wilson. (2 copies.)

Communication from Chief Engineers relative to a bill entitled "A Bill to confirm the survey of the Pueblo of San Francisco." (2 copies.)

Report of Survey of Dan River from Clarksville to Danville, Va. S. Thayer Abert. (2 copies.)

A copy of Report upon Survey of Mobile Harbor, Alabama. Capt. A. N. Damrell. (2 copies.)

A Report upon Survey of the harbor of Mobile. Capt. A. N. Damrell. (2 copies.)

Copies of Reports of Pamunkey and Archer's Hope Rivers, Va., of Lockwood's Folly and Waccammaw Rivers, North Carolina; and of Pee Dee River, South Carolina. Capt. C. B. Philips. (2 copies.)

Copy of Report of Surveys of York River and of Lynn Haven, Link Horn and Broad Bays, Virginia. Capt. C. B. Philips. (2 copies.)

Report of Survey of Kankakee River, in Indiana and Illinois. Maj. J. A. Smith. (2 copies.)

Report of Survey of Green River and its tributaries, Muddy and Barren rivers, Kentucky. Col. Wm. E. Merrill. (2 copies.)

Papers relative to the payment of first installment of compensation to Mr. James B. Eads for maintenance, of channel at South Pass, Mississippi River, October 30, 1879. (Copies for distribution.)

Report of the Board of Engineers on the Improvement of the Wisconsin River. (2 copies.)

Report of Committee, on Railways and Canals (H. R.) to obolish all tolls, on the Louisville and Portland Canal. (2 copies.)

Information relative to the Improvement of the Harbor at Grand Haven, Mich. Maj. F. Hanwood. (2 copies.)

Report of Examinations and Surveys made in compliance with River and Harbor Act, of Naticoke River, Delaware and Maryland;

Broad Creek, Northeast River, Tuckahoe Creek, Slaughter Creek and Cabin Creek, Maryland, and Chincoteague Inlet, Virginia. Maj. W. P. Craighill. (2 copies.)

Report upon the Improvement of Alton Harbor, together with a map of the Mississippi River in that vicinity. Col. J. H. Simpson. (2 copies.)

Report of an Examination and Survey of Gasconade River, from its mouth to Vienna, in Marie's Co., Missouri. Maj. C. R. Suter. (2 copies.)

A Report of the Survey of the Connecticut River below Hartford, Conn. Gen. G. K. Warren, (2 copies,)

Report in relation to Inland Water Routes from Norfolk, Va., to the Atlantic Ocean, south of Cape Hatteras, &c. Capt. C. B. Philips. (2 copies.)

Report of the Survey of Allegheney River from French Creek to Olean, N. Y. Col Wm. E. Merrill. (2 copies.)

From De Volson Wood, Hoboken, N. J.:

Quarternions. Prof. De Volson Wood. Vol. III., No. 3. May, 1880.

From Frank W. Whitlock. W. Newton, Mass.:

Canal de Nicaragua. Exposé de la Question. M. Felix Belly. Paris. 1859.

From Lucien N. B. Wyse, Paris, France:

Rapports sur les Études de la Commission Internationale d'exploration de l'Isthme American. L. N. B. Wyse, Armand Reclus, P. Sosa. Paris, 1879.

From other sources:

The American Catalogue. Author and Title Entries of Books in print and for sale (including reprints and importations) July 1, 1876. Lynd E. Jones. New York. 1880.

Library Journal. Vol. V., Nos. 3 and 4.

Bernard Quaritch's letter to General Starring. Jan. 14, 1880.

Report of Special Committee of Board of Trade of San Francisco on Interoceanic Canal San Francisco. 1880.

Annual Report of the Engineer and Manager Toronto Water Works, for 1879.

L'État et les Chemins de fer en Angleterre. Lettre addresse Commission des *Annals des Ponts et Chaussees* par Ch. de Franqueville.

ANNOUNCEMENTS.

The following resolutions were adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications :

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of the differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door east from Fourth avenue, and near the southwest corner of Grammercy Park. It is open from nine o'clock A.M. to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P.M.

The Library and Conversation Rooms will also, for the present, be open every *Wednesday evening* from 7½, to 10 P. M., and during the cooler months every *Saturday evening*, also for the same hours. The rooms will *not* for the present be open on *Thursday evenings*. Members are invited to avail themselves of the opportunities afforded on these evenings, both for consultation of books and periodicals and for conversation.

LIST OF MEMBERS.

ADDITIONS.

HONORARY MEMBERS.

		Date of Election.
DIRKS, JUSTIN	Chief Engineer "Waterstaat" and the Canal from Amsterdam to the Sea, Amsterdam, Holland	June 2, 1880.
WEBER, MAX MARIA, BARON VON	Imperial Councillor, Berlin, Germany	June 2, 1880.

MEMBERS.

CURRIE, DAVID MCN	Assistant U. S. Engineer, 404 Market St., St. Louis, Mo	May 5, 1880.
DEFREES, MORRIS M	29 Court House, Indianapolis, Ind	May 5, 1880.
HUGHES, WILLIAM M	Assistant City Engineer, Cincinnati, Ohio	June 2, 1880.
KELLOGG, CHARLES	(Kellogg & Maurice), Athens, Bradford Co., Pa	June 2, 1880.
MACNAUGHTON, JAMES	Albany, N. Y	May 5, 1880.
MANLEY, HENRY	Assistant City Engineer, Boston, Mass	June 2, 1880.
MORSE, HENRY G	Morse Bridge Co., Youngstown, Ohio	April 7, 1880.
ROBINSON, ALBERT A	Chief Engineer Atchinson, Topeka and Santa Fe Railroad, Pueblo, Col	May 5, 1880.

SMITH, CHARLES A.....Washington University, St. Louis, Mo. April 7, 1880.
TINTORER, JOSE GIBERGA. Union 7 pr., Barcelona, Spain.....May 5, 1880.
WEIR, CHARLES G.....Assistant U. S. Engineer, 24 East Tenth St., New York City, N. Y.....May 5, 1880.
YONGE, SAMUEL H.....Assistant U. S. Engineer, P. O. Box 26, St. Charles, Mo.....May 5, 1880.

ASSOCIATES.

BAUMANN, EDWARD.....Architect, 59 Metropolitan Block, Chicago, Ill.....June 2, 1880.
BELCHER, GEORGE W. C..Belcher Sugar Refining Co., St. Louis, Mo.....May 5, 1880.
BURR, WILLIAM H.....(Elected Junior, June 3, 1874), Rensselaer Polytechnic Institute, Troy, N. Y.....May 5, 1880.

JUNIOR.

CROSBY, BENJAMIN L.....Assistant Engineer, Plattsmouth Bridge, Plattsmouth, Neb.....June 2, 1880.

CHANGES AND CORRECTIONS.

MEMBERS.

ALLEN, C. FRANK.....Engineers' Office A., T. and S. F. RR., Pueblo, Colorado.
AUCHINCLOSS, WILLIAM S. 209 Church St., Philadelphia, Pa.
BAXTER, GEORGE S.....209 East Eighteenth St., New York City, N. Y.
BELKNAP, MORRIS S.....Corner Eighth and Oak Sts., Louisville, Ky.
DAVIS, JOSEPH P.....Room 23, Western Union Building, New York City, N. Y.
DURHAM, C. WHEELER...154 Michigan Ave., Chicago, Ill.
EARLEY, JOHN E.....Locating Engineer, A. and P. RR., Albuquerque, N. M.
GREENWOOD, WILLIAM H. Care of Santiago Lohse, 4 Calle de San Manuel, City of Mexico, Mexico.
KATTE, WALTER.....Chief Engineer Midland Improvement Co., 20 Nassau St., Room 5, New York City, N. Y.
LOW, GORHAM P., Jr.....Care of St. Paul Union Depot Co., St. Paul, Minn.
MARSLAND, EDWARD.....Sing Sing, N. Y.
NEWTON, WILLIAM H....490 Webster Ave., Chicago, Ill.
NOBLE, ALFRED.....Sault Ste. Marie, Mich.
OSGOOD, JOSEPH O.....Milton, Mass.
ROTCH, WILLIAM.....Jamaica Plain, Mass.
SEDGWICK, THOMAS S....Rockport, Aransas Co., Texas.
SHREVE, SAMUEL H.....31 East Thirty-first St., New York City, N. Y.
STRIEDINGER, JULIUS H..85 East Tenth St., New York City, N. Y.
UNTHANK, A. W.....Tucson, Arizona.
WALLING, HENRY F.....98 Trowbridge St., Cambridge, Mass.
WARFIELD, ALBERT G., JR. Oakdale, Florence P. O., Howard Co., Md.

JUNIOR.

REEVES, DAVID.....410 Walnut St., Philadelphia, Pa.

DECEASED.

HARDEE, THOMAS S.....New Orleans, La. (Elected Member April 4, 1877); died May 21, 1880.

HJORTSBERG, MAX.....Chicago, Ill. (Elected Member November 22, 1872); died May 16, 1880.

FORD, ARTHUR L.....Panama, C. A. (Elected Associate November 6, 1872); died May 30, 1880.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VI.—July, 1880.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

JUNE 16TH, 1880.—The Society met at 8 P. M. Vice-President Chanute in the Chair.

The death of Arthur L. Ford, Associate A. S. C. E., which occurred at Panama, May 30th, 1880, was announced, and Messrs. M. N. Forney, O. Chanute and Charles Macdonald were appointed a committee to prepare a memoir for publication.

A paper by Martin Coryell, Member A. S. C. E., subject "Cheap Transportation *versus* Rapid Transit and Delivery," was read by the author, and discussed by Messrs. Chanute, Coryell, Dresser, Forney, Macdonald, North, Strang and von Weber.

JULY 7TH, 1880.—The Society met at 8 P. M. Ashbel Welch in the Chair.

The provisions of the Constitution and By-Laws regarding nominations, balloting and elections to membership in the Society, together with suggested modifications of these provisions, were discussed by

William Metcalf (by letter), and by Messrs. Andrews, Baxter, Bogart, Cooper, Croes, North, Welch and Yardley.

The election to Honorary Membership and the acceptance of their election by John Ericsson, of New York, Justin Dirks, of Amsterdam, Holland, and M. M. Baron von Weber, of Berlin, Germany, was announced.

Ballots were canvassed, and the following candidates declared elected: As Members—Smith S. Leach, Corps of Engineers, U. S. A., St. Louis, Mo.; John A. Ockerson, St. Louis, Mo.; William N. Radenhurst (elected Junior July 7th, 1875), Rochester, N. Y.; Hart Vance, St. Louis, Mo. As Associate—Henry B. Hammond, New York. As Juniors—Stephenson Waters Fox, St. Louis, Mo.; Ellis B. Noyes, Boston, Mass.

OF THE BOARD OF DIRECTION.

June 9th, 1880.—Applications were considered. Action was taken as to Members in arrears. Appropriations were made.

July 13th, 1880.—Applications were considered. Under the provisions of Section 1 of the By-Laws the further meetings of the Society during the months of July and August were directed to be suspended. The rooms of the Society will be open during these months each Wednesday evening from 7:30 to 10 o'clock.

LIST OF NEW BOOKS ON

ENGINEERNG AND TECHNOLOGY

Arches: Theory of solid and braced elastic arches; applied to arch bridges and roofs in iron, wood, concrete or other material; graphical analysis reprinted from *Van Nostrand's Magazine*. W. Cain, New York. 12mo., illus. (Science Series, No. 48.) *Van Nostrand*. $0.50.

Architecture: Glossary of Terms used in Grecian, Roman, Italian and Gothic Architecture. J. H. Parker, New York. 16mo., illus. *Scribner & Welford*. $3.00.

Arms: American inventions and improvements in breech-loading small arms, heavy ordnance, machine guns, magazine arms, fixed ammunition, pistols, projectiles, explosives, and other munitions of war, incl. a chapter on sporting arms. C. B. Norton, Springfield, Mass. Quarto, illus. *Chapin & Gould*. $10.00.

Bridges: Modern Examples of Road and Railway Bridges; illustrating the most Recent Practice of Leading Engineers in Europe and America. Partially reprinted from *Engineering*. 94 plates. Folio. W. H. Mawand J. Dredge. London. *Engineering*. 42s.

Camping: How to camp out; hints for camping and walking. Knapsack ed. J. M. Gould, New York. *Scribners*. $0.75.

Drawing: Draughtman's hand-book of plan and map drawing, with instructions for preparation of engineering, architectural and mechanical drawings. G. C. André, London. 4to. plates. *Spous, New York*. $3.75.

——: Hand-book of drawing; with upward of 200 woodcuts and diagrams. 1st Amer. from 2d Eng. ed. W. Walker. 12mo. New York. *Scribners*. $1.75.

——: ——; Mathematical drawing instruments, and how to use them. F. E. Hulme, New York. 12mo. *Bicknell & Comstock*. $1.50.

Electric Light: Its Production and Use. Embodying Plain Directions for the Working of Galvanic Batteries, Electric Lamps, and Dynamo-Electric Machines. J. W. Urquhart, C. E. Edited by F. C. Webb. London. 8vo., illus. *Crosby Lockwood*. (Announcement.)

Excavation and Embankment Tables, for the

rapid and accurate finding, directly from cross-section notes, of the cubic contents of railroad excavations and embankments. Edited by C. and C. Pullen, Chicago. 8vo., plates. *J. M. W. Jones.* $5.00.

Export: American export trade guide for buyers in foreign countries; cont. an accurate list of American manufacturers, exporters and commission merchants, in all parts of the U. S.; articles of merchandise exported alphabetically arr. and classified under their respective headings; foreign steamship and shipping lines. New York. 16mo. *T. G. Kent & Co.* $2.50.

Eyesight: good and bad. Treatise on the exercise and preservation of vision. R. B. Carter. Philadelphia. 12mo., illus. *Presley Blackiston.* $1.50.

Field Engineer: Hand-book of Practice on the Survey, Location, and Track-work of Railroads. W. Findlay Shunk. New York. 12mo. *Van Nostrand.* $2.50.

Fluid Motion: Elements of the mathematical theory of fluid motion; motion of a solid in a fluid; vibrations of liquid spheroids. Reprinted from *Van Nostrand's Magazine.* J. Craig. New York. (Science Series No. 49.) *Van Nostrand.* $0.50.

Geology: Engineering Geology. With colored Maps and Illustrations. W. H. Penning. London. 8vo. *Bailliere.* 3s. 6d.

Graphic Statics. G. Sydenham Clarke. London. 4to., illus. *Spous, New York.* $6 50.

Inter-Oceanic Canal: The American Inter-Oceanic Canal Quession. Rear Admiral D. Ammen, U. S. N. Philadelphia. 8vo. *Hamersly.*

—— ——: Inter-Oceanic Canal and the Monroe Doctrine. New York. 12mo. *Putnams.* $1.00.

Library Key: An index of general reading. F. A. Archibald. New York. 8vo. *Phillips & Hunt.* $1.00.

Lightning Conductors: Their history, nature and mode of application. R. Anderson. London. 8vo. *Spous, New York.* $6.50.

Linkages: The different forms and uses of articulated links; tr. from *Revue Universelle des Mines,* and reprinted from *Van Nostrand's Magazine.* J. D. C. de Roos. New York. (Science Series, No. 47.) *Van Nostrand.* $0.50.

Machine Drawing Copies: A series of Lithographed Working Drawings of the most important parts of Machines and Engines. W. Busbridge. London. *Spous. New York.*

Mine Drainage: Being a Complete and Practical Treatise on Direct-Acting Underground Steam-Pumping Machinery. Stephen Michell. London. 8vo., illus. *Crosby Lockwood.* (Announcement.)

Mining: Lectures delivered at the School of Mines, Paris, by J. Callou, Inspector General of Mines. Translated by C. L. Foster and W. Galloway. Paris. 8vo. Atlas. Plates. 3 vols. *Dunod,* Paris. *Dulau,* London. Per vol. 26s.

Mineralogy: Elementary guide to determinative mineralogy, for the use of the practical mineralogist and prospector, and for instruction in schools and academies; based upon the method of Weisbach's Tabellen zur bestimmung der minerallen; applied chiefly to American species. C. Gilbert Wheeler, Chicago. 12mo. *S. J. Wheeler.* $1.00.

Patent Case Index: Containing lists of all cases involving patents for inventions, as reported in the State and Federal reports, Robb's patent cases, and Patent Office Gazette, to present time; with brief synopsis of law points decided, arr. alphabetically. W. P. Preble, Jr. Boston. 12mo. *Little, Brown & Co.* $5.00.

Railroads: Permanent Way, Rolling Stock and Technical Working of Railways. Charles Couche, Inspector General of Mines, Paris, Vol. I. translated by James N. Schoolbred. Vol. II., translated by J. Edwards Wilson. London. 4to. Text. Folio Atlas. *Dunod,* Paris. *Dulau,* London. To be completed in 4 vols. Vol. 1, £2; Vol. 2, £5.

——: Taxation of Railroads and Railroad Securities. C. F. Adams, Jr. New York. 12mo. *Railroad Gazette.* $0.25.

——; Federation of the Railroad System; argument, Feb. 27, 1880, before the Committee of Commerce of U. S. House of Representatives, on the bills to regulate Inter-State Railroad Traffic. Chas. Francis Adams, Jr. Boston. 8vo. *Estes & Lauriat.* $0.20.

Roads: Hints to highway surveyors on the repair of main roads. W. H. Wheeler. London. 8vo. *Spous, New York.* $0.20.

Royal Engineers: Professional Papers of the Corps of Royal Engineers. Series of Occasional Papers. Vol. 3, 1879 Edited by Major R. H. Vetch, R. E. With numerous plates. 8vo., pp. 408. (*Royal Engineer Institute, Chatham,* 12s.

Sanitary Science: Brain work and overwork. H. C. Wood, Jr., M. D. (American Health Primers.) Philadelphia. 32mo. *Presley Blackiston.* $0.50.

—— ——: Cleanliness and Disinfection. Elisha Harris, M. D. New York. 16mo. *Putnams.* $0.08.

—— ——: Dwelling Houses; Their Sanitary Construction and Arrangement. W. H. Corfield, M. A., M. D. (Van Nostrand's Science Series.) 18mo. New York. *D. Van Nostrand.* $0.50.

—— ——: Public Health, Reports and Papers. Vol. IV. Presented at the meetings of the Am. Public Health Assn., 1877–1878. Boston. 8vo. *Houghton, Osgood & Co.* $5.00.

Sewage Disposal. Henry Robinson. London. 8vo. *Spous, New York.* $150.

Sewers and Drains for Populous Districts. Julius W. Adams, Chief Engineer to the Board of City Works, and Consulting Engineer to the Board of Health, Brooklyn. 8vo, illustrated. New York. *Van Nostrand.* $2.50.

Specifications: Hand-book of Specifications; or, Practical Guide to the Architect, Engineer, Surveyor, and Builder, in drawing up Specifications and Contracts for Works and Constructions. With Preliminary Essay, Forms of Specifications and Contracts, &c., &c., with numerous illustrations. T. Donaldson. London. 8vo. *Crosby Lockwood.* £1, 11s. 6d.

Steam Boilers; Practical treatise on high

pressure steam boilers; including results of recent experimental tests of boiler materials; with description of approved safety apparatus, steam pumps, injectors and economizers in actual use. W. M. Barr. Indianapolis, Ind. 8vo. Illus. *John Bros.* $4.00.

Steam Engine: Corliss Engine and Allied Steam Motors, working with or without Automatic Expansion-gear; including the most approved Designs of all Countries, with special reference to the Steam Engines of the Paris International Exhibition of 1878. Translated from the German of W. H. Uhland, by A. Tolhausen, C. E. In two vols. 4to, and Atlas of about 60 Photo-lithographed Drawings. London. *Spous, New York.* $32.00.

—— ——: Richards' Steam Engine Indicator. Charles T. Porter. Revised with large additions, by F. W. Bacon. New York. 12mo. Illus. *Van Nostrand.* $1.00.

Steel: Its History, Manufacture and Uses. J. S. Jeans, Sec. Iron and Steel Inst. of Great Britain. London. 8vo. Plates and Illus. *Spous, New York.* $14.50.

Traverse Tables: Traverse Tables computed to Four Places of Decimals for every Degree of Angle, up to 100 of Distance, for the use of Surveyors and Engineers. R. L. Gurdon. London. Folio. *Griffin.* 30s.

Valves: The Slide Valve Practically Explained. Embracing Simple and complete Practical Demonstrations of the Operations of each Element in a Slide Valve Movement, &c. Joshua Rose. Philadelphia. 8vo. *H. C. Baird & Co.* $1.00.

Water Analysis for Sanitary Purposes. With Hints for the Interpretation of Results. E. Faukland. Philadelphia. 12mo. Illus. *Presley Blakiston.* $1.00.

Water and Gas Works. Remarks on the Ratings of. Joseph Quick, Jr. London. 8vo. Illus. *Spous. New York.* $1.00

Wire Gauge: Birmingham Wire Gauge. Correct values of the Birmingham Wire Gauge in 100ths of an inch, &c. John Watkins. On a card. London. *Spous, New York.* $0.10.

—— ——; English Wire Gauge: With descriptive table, and drawing. T. Hughes. London. 8vo. *Spous, New York.* $1.00.

—— ——: Report of the Committee of the Society of Telegraph Engineers on the Birmingham Wires Gauge, by C. V. Walker; together with Papers on the Unit of the Birmingham Gauge. And on the Birmingham Wire Gauge, by Latimer Clarke. London. 8vo. pp. 39. *Spon.* 1s.

THE NORMAN MEDAL.

CODE OF RULES FOR ITS AWARD.

I.—Competition for the Norman Medal of the American Society of Civil Engineers shall be restricted to Members of the Society.

II.—There shall be one gold medal, and only one, struck for each and every fiscal year of the Society, and awarded as hereinafter provided. The dies therefor shall be with the Superintendent of the United States Mint at Philadelphia, in trust exclusively for the above purpose. Such medal shall be of a cost equal to the annual interest received upon $1 000 of the Consolidated Stock of the City of New York, Certificate No. 179, of the additional new Croton Aqueduct Stock of the City of New York, authorized by an Act of the Legislature of the State of New York, Chap. 230, passed April 15th, 1870, dated November 17th, 1873, now held in trust by the Treasurer of this Society, and so held solely for this purpose, and shall be executed upon his order.

III.—All original papers presented to the Society by members of any class, during the year for which the medal is awarded, shall be open to the awards, provided that such papers shall not have been previously contributed in whole or in part to any other association, nor have appeared in print prior to their publication by the Society, nor have been presented to the Society in any previous year.

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members of the Society, to be designated by the Board of Direction. The Secretary of the Society shall act as Secretary to the Board of Censors.

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ANNOUNCEMENTS.

The next regular meeting of the Society will be held Wednesday, September 7th, 1880, at 8 P. M. A paper by J. Vincent Browne, C. E., on the Harbor Improvements of Quebec, Canada, will be read and discussed.

During July and August the Society rooms will be open as usual during the day, and also on each Wednesday evening from 7½ to 10 o'clock.

The following resolutions were adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of the differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door east from Fourth avenue, and near the southwest corner of Grammercy Park. It is open from nine o'clock A.M. to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P.M.

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LIST OF MEMBERS.

ADDITIONS.

HONORARY MEMBERS.

Date of Election.

ERICSSON, JOHN.....36 Beach St., New York City, N. Y..October 2, 1879.

CHANGES AND CORRECTIONS.

COGSWELL, WILLIAM B.....41 McBride St., Syracuse, N. Y.

COPELAND, GEORGE M.....24 Park Place, Room 17, New York City, N. Y.

HARDING, HENRY.....Care of Richmond and Southwestern Railway, Pearisburg, Giles Co., Va.

MOORE, CHARLES E.....Care of Crane Bros. Mfg. Co., Chicago, Ill.

NICOLLS, WILLIAM J.....General Office Long Island Railroad, Long Island City, N. Y.

ROTCH, WILLIAM.....Consulting Engineer and Purchasing Agent, Mexican Central Railway Company, 87 Milk St., Boston, Mass.

SEYMOUR, CHARLES.....Chief Engineer Lookout Mountain Railroad (from Chatanooga, Tenn., to Rome, Ga.), Chatanooga, Tenn.

STEARNS, FREDERICK P.....Ass't Engineer Improved Sewerage Works, Atlantic, Mass.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VI.—August, 1880.

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ADDITIONS TO

LIBRARY AND MUSEUM.

From Administration des Ponts et Chaussées, Paris:

Annaes. April and May, 1880.

From American Chemical Society. P. Cassamajor, Secretary, New York:

Journal of the Society. Vol. II., Nos. 1, 2, and 3.

From American Institute of Architects, H. M. Congdon, Secretary, New York;

Proceedings of Thirteenth Annual Convention, held in New York, November 19th and 20th, 1879.

From American Iron and Steel Association, James M. Swank, Secretary, Philadelphia;

Annual Report of the Secretary for 1879.

From C. A. Angstrom, Stockholm, Sweden:

Handbok för Beräkning och Byggnad af Turbiner och Turbin-Pumpar. Stockholm, 1880.

From Argentine Scientific Society, Don Eduardo Aguirre, Secretary, Buenos Ayres:

Anales. February, April and May, 1880.

From Charles E. Billin, Philadelphia:

On the Gothard Railroad. Charles E. Billin (5 copies.)

From Boston Society of Civil Engineers, Fred'k Brooks, Librarian, Boston:

Proceedings. April, 1880.

From G. Bouscaren, Cincinnati, Ohio:

Report on the progress of work and cost of completing and maintaining the Cincinnati Southern Railway. G. Bouscaren, Cincinnati, 1880. (Copies for distribution.)

From Robert Briggs, Philadelphia:

The Decimal Gauge. Robert Briggs. Philadelphia, 1880.

From Francis Collingwood, New York:

Specifications for Steel Wire Ropes for the Over-Floor Stays and Storm Cables of the East River Suspension Bridge. 1880.

Specifications for Steel Suspenders, Connecting Rods, Stirrups and Pins for the East River Suspension Bridge. 1880.

Specifications for the Construction of a Bridge on the line of the East River Bridge across Franklin Square, in the City of New York. June, 1880. (Several copies.)

From Commissioners of Second Geological Survey of Pennsylvania. Wm. A. Ingham, Secretary. Philadelphia:

Report of Progress in Indiana County. W. G. Platt. Harrisburg, 1878.

The Geology of Lawrence County. A special Report on the Correlation of the Coal Measures in Western Pennsylvania and Eastern Ohio. I. C. White. Harrisburg, 1878.

The Geology of Mercer County. I. C. White, Harrisburg, 1880.

The Permian or Upper Carboniferous Flora of West Virginia and Southwestern Pennsylvania. Wm. M. Fontaine and I. C. White. Harrisburg, 1880.

From Joseph P. Cotton, Newport, R. I.:

Lithograph Map of the Battlefield of Five Forks.

From J. James R. Croes, New York:

A Table of general information concerning the Water Works of the United States and Canadas. C. G. Hildreth, Lockport, 1878.

From Dyckerhoff and Söhne, Amöenburg, Germany:

Proceedings of the General Convention of the German Society of Cement Manufacturers and the Sessions of the Society of Manufacturers of Bricks, Hollow Ware, Lime and Cement, February 5th, 6th and 7th, 1880. (German.)

From Capt. James B. Eads, St. Louis:

The preliminary report of the Mississippi River Commission.

From Engineer Department, U. S. A., Washington, D. C.:

Report upon the Blasting Operations at Lime Point, Cal., in 1868 and 1869. Col. George H. Mendell.

From M. N. Forney, New York:

Improved Tank Locomotives. M. N. Forney.

From Hiram F. Hills, Boston;

Experiments upon Piezometer used in Hydraulic Investigations. Hiram F. Hills, Boston, 1878.

From Institution of Civil Engineers, James Forrest, Secretary, London:

Minutes of Proceedings. Vol. LIX.

Abstracts of papers published in Foreign Transactions and Periodicals. Vol. LX. Session 1879-80. Part II.

Excerpt Minutes of Proceedings. Edited by the Secretary, as follows:

The use of Asphalt and Mineral Bitumen in Engineering. William H. Delano.

Bridge over the Monongahela River at Port Perry, Pa. Joseph M. Wilson.

Fire Hydrants, with description of one in use at Halifax, N. S. Edward H. Keating.

Fixed and Movable Weirs. L. F. Vernon Harcourt.

Movable Dams in Indian Weirs. Robert B. Buckley.

Dredging operations on the Danube between Pressburg and Gönyö, in Hungary. Murray Jackson.

The River Nile. Benjamin Baker.

Iron and Steel at Low Temperature. John J. Webster.

The Theory of Modern American Suspension Bridges. Celeste Clericetti.

The regulation of the Waters of the Jura. C. de Graffenried.

New Zealand Light-houses. John Blackett.

From L. J. Le Conte, Oakland, Cal.:

Report of the State Engineer of California for 1879. William Ham Hall.

From Wm. H. McFadden, Chief Engineer Water Department, Philadelphia:

Annual Report of the Water Department of Philadelphia for 1879.

From McGill College and University, Montreal;

Annual Calendar. Session 1880–81.

From Simon Newcomb, Superintendent American Ephemeris, Washington, D. C.:

A Transformation of Hansen's Lunar Theory compared with the Theory of Delaunay. Simon Newcomb. Washington, 1880.

From Gen. John Newton, Corps of Engineers U. S. A., New York:

Annual Report on the removal of obstructions at Hell Gate. Gen. John Newton. Washington, 1877.

From New York Meteorological Observatory, Daniel Draper, Director, Central Park, New York:

Abstracts from Self-Recording Instruments. April and May, 1880.

From Edward P. North, New York:

Reports of the Executive Committee and Treasurer of the New York Bridge Company, Brooklyn, 1872.

Report of Chief Engineer of East River Bridge on Prices of Materials and estimated cost of the Structure. June 28, 1872.

Pneumatic Tower Foundation of the East River Suspension Bridge. New York, 1872.

Report of Board of Consulting Engineers appointed to recommend a plan for the New York and Long Island Bridge across the East River at Blackwell's Island.

Memoir of the Iron Bridge over the Missouri River at St. Joseph, Mo. Built in 1871–2–3.

A method of constructing Bridge Piers and the substructure of Wharves or other Harbor Works. S. B. Cushing. Providence, R. I., 1870.

Calculation of Strain on Members of Girders continuous over Supports. Prof. Charles A. Smith. St. Louis, 1873.

The effects of High Atmospheric pressure, including the Caisson Disease. A. H. Smith, M. D. Brooklyn, 1873.

Bullion Its production and use. Compiled by the Editor of *Bullion*. New York, 1880.

Chimney Construction. R., M. Bancroft. London, 1878.

Reports of the Department of Public Works, City of New York, for Quarters ending Dec. 31, 1877, Dec. 31, 1878, March 31, and Sept. 30, 1879.

Annual Reports of the Department of Public Works, City of Chicago, for 1873, 1876 and 1878.

Fitz John Porter, Commissioner of Public Works, to Andrew H. Green, Comptroller of the City of New York, Dec. 2, 1875.

Annual Report of the Harbor Commissioners of Montreal for 1878.

Annual Report of the Chief of Engineers for year ending June, 1878. Vol. II. Parts 1 and 2.

Annual Report of the Ontario Silver Mining Company, for year ending Jan. 31st, 1878.

Annual Report of the State Engineer and Surveyor, on the Canals of the State of New York, for 1878. (2 copies.)

Report of the Committee on the Affairs of Cities, to the Assembly of New York, April, 1880, as to the present system of Street Cleaning in the City of New York, and the means whereby a more efficient and economical method of doing the work may be secured.

Annual Report of the James River Improvement Commission, for 1879.

The Delta of the Mississippi; the physics of the river, the control of its floods, and the redemption of the alluvion. Prof. C. G. Forshey, Cambridge, 1873.

Report on the Mississippi Jetties, August 18, 1876. Capt. James B. Eads.

Hydraulic Lime of Teil and French Cements. H. Champin and Gillet. New York, 1873.

A resolution (H. R.) of March 20, 1872, relative to removing the Light-house at New Haven harbor to Southwest Ledge. Hon. S. W. Kellogg.

The Strength of Wrought Iron, as affected by its Composition and by its Reduction in rolling. A. L. Holley, Ph. B.

The Hayford Process and Apparatus for Preserving Timber. Edward R. Andrews.

Proceedings of the Roadmasters Meeting of the Atlantic and Great Western Railroad, held at Meadville, Pa., Nov. 14, 1878.

Notes on the Mineral District of Minora. Isaac Saffrans.

On the Relation of Moisture and Air to Health and Comfort. Robert Briggs.

Statement of E. J. Lewis, showing why he should not be removed as Superintendent 23d and 24th Wards, Department Public Parks, Aug. 13, 1879.

Statement by Commissioner Smith E. Lane, of the Violations of Law, and Irregularities in the Department of Public Parks, on the part of Commissioners Wenman, Wetmore and Conover, in answer to the letter of Mayor Cooper, Sept. 9, 1879, calling for such statement.

The National Advantages of Government Aid to American Commerce. Wm. P. Clyde, New York, 1880.

Specifications of the Boundary street intercepting Sewer.

Specifications for laying Granite Block Pavement in the City of Washington, D. C., 1879.

Specifications for completing and equipping with rolling stock, and all necessary appurtenances, the railroad of the New York City and Northern Railroad Co., from Highbridge, in the City of New York, to the New York, Harlem and Albany Railroad, in the town of South East, Putnam Co., N. Y.

Seventh Annual Report of the Trustees of the Metropolitan Museum of Art, May 17, 1877

Foundation of the Washington National Monument. Washington, 1873.

A paper relating to Fraction Engines or Road Locomotives. The past, the present and the future of Steam on the Common Road. Prof. R. H. Thurston, Philadelphia, 1872.

Report of the American Scientific Commission on the Artificial Waterways of Europe, with special reference to the Tehuantepec Railway and Ship Canal. 1871.

Interoceanic Canal. Practibility of the different routes, and questionable nature of the interest of the United States in a Canal. J. Lawrence Smith.

Tehuantepec Railway, 1879. Grant by the Government of Mexico to Edward Learned,

of Pittsfield, Mass., for construction of Railways and Telegraph Lines, with control of Ports on both sides of the Isthmus. Dated June 2, 1879.
Third Annual Report of the Water Commissioners of the City of Lowell, Mass., 1873.
Official Catalogue, International Exhibition, Philadelphia, 1876. Part I., Main Building and Annexes.
Official Catalogue, International Exhibition, Philadelphia, 1876. Part II., Department IV. Art.
Official Catalogues of the Austrian, German, Russian and New South Wales Departments, International Exhibition, Philadelphia, 1876.

From North of England Institute Mining and Mechanical Engineers, Theo. Wood Bunning, Secretary, Newcastle-on-Tyne, England :
Transactions. February, March, April and May, 1880.

From Publishers Revue Generale des Chemines de fer, Edgar Monjean, Secretary, Paris :
Revue Generale des Chemins de fer. February, March and April, 1880.

From Royal United Service Institution, Capt. B. Burgess, Secretary, London:
Journal of the Institute. Vol. XXIV. No. CIV.

From Hon. Horatio Seymour, Jr., State Engineer and Surveyor, Albany, N. Y.:
State Engineer's Report on Railroads of the State of New York, for 1878.

From Charles A. Smith, St. Louis:
Proposals, Contract and Specifications for Hydraulic Pumping Machinery, Richmond Water Works.

From Societe des Ingenieurs Civils, Paris :
Memoires. April, 1880.

From St. Louis Public School Library, Fred. M. Crunden, Librarian, St. Louis :
Bulletin of the Library. Nos. 5 and 6. September–December, 1879.

From Joseph W. Turtle, Newark, N. J.:
Congressional Directory. Second Session. 46th Congress. F. A. Richardson.

From University of Tokio, H. Kato, President, Tokio, Japan :
Calendar of the Departments of Law, Science and Literature, for 1879–80.

From United States Light-house Board, Washington, D. C.:
List of Beacons, Buoys, Towers and other Day-Marks, in the First Light-house District. Corrected to May 1, 1880. (2 copies.)

From United States Naval Institute, Annapolis, Md.:
Proceedings of the Institute. Vol. VI., No. 2.

From Gen. Horatio G. Wright, Chief of Engineers, U. S A., Washington, D. C.:
Report of Board of Engineers for fortifications, and for river and harbor improvements : the suggestion of the Chief of Engineers that the unexpended balances of the appropriations of June 18, 1878, and March 3, 1879, be applied to the improvement and dredging, &c., of the mouth of Red River.
Report upon examination of Broad River, South Carolina, made in compliance with law. Gen. Q. A. Gilmore.
Report on a survey of the entrance to Cumberland Sound, Florida, made in accordance with River and Harbor Act, March 3, 1879. Gen. Q. A. Gilmore.
Communications from Chief of Engineers on reports of Capt. Chas. B. Phillips, of examinations made in accordance with law, of Catawba, Wateree and Santee rivers.
A letter of Chief of Engineers accompanying copy of report on surveys of St. Mary's River, Mich., made in compliance with law. Gen. G. Weitzel.
Copies of reports on survey made of Superior Bay, for the improvement of harbor at head of Lake Superior. Capt. Charles J. Allen.
Report on survey made in compliance with requirements of River and Harbor Act, of March 3, 1879, of the Mississippi River, opposite the mouth of the Missouri. Col. J. H. Simpson.
Widening the channel at Rock Island Rapids.
Report in relation to the mining debris in the Sacramento River. Col. Geo. H. Mendell.
Reports respecting the entrance of Yaquina Bay, Oregon.
The removal of Wrecks which may obstruct navigation.

From Joseph M. Wilson, Philadelphia :
The bridge over the Monongahela River at Port Perry, Pa. Jos. M. Wilson.

From William E. Worthen, New York :
Report upon the Construction of Relief Sewers in the City of Brooklyn, N. Y. Wm. E. Worthen and Robert Van Buren. Brooklyn, 1878.

From other sources:
The Library Journal. Vol. V., Nos. 5 and 6.

LIST OF MEMBERS.

ADDITIONS.

MEMBER.

Date of Election.

OCKERSON, JOHN A.....U. S. Assistant Engineer, 2828 Washington Ave., St. Louis, Mo.....July 7, 1880.

JUNIORS.

FOX, S. WATERS.....U. S. Assistant Engineer, 1351 Washington Ave., St. Louis, Mo.....July 7, 1880.

NOYES, ELLIS B.....U. S. Naval Station, New London, Conn.....July 7, 1880.

REUSCHEL, WILLIAM.....Assistant Engineer, Cleveland Bridge and Car Works, Cleveland, Ohio..June 2, 1880.

CHANGES AND CORRECTIONS.

NICHOLSON, GEORGE B ...Chief Ass't. Engineer Knoxville and Cincinnati Southern Railway, Knoxville, Tenn.

PEARSONS, GALEN W.....Kansas City, Mo.

SCHMIDT, MAX E.....U. S. Ass't. Engineer, 404 Market St., St. Louis, Mo.

STEPHENS, CLINTON F....Chief Engineer Texas and St. Louis Railway, Tyler, Tex.

WALLING, HENRY F.....U. S. Coast and Geodetic Survey, Washington, D. C.

JUNIORS.

GLASKIN, EDWIN E.....52 Queen Victoria St., London, England.

HORTON, SANFORD. .....Engineer Dep't. N. M. and S. P. R. R., Silver City, N. M.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VI.—September, 1880.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

SEPTEMBER 1ST, 1880.—The Society met at 8 P. M. Charles H. Haswell in the Chair.

The death of James A. Hayward, Member A. S. C. E., was announced.

A paper by J. Vincent Browne, C. E., on the "Quebec Harbor Improvements," and a paper by L. G. F. Bouscaren, Member A. S. C. E., on "Experiments on Wrought Iron Columns," were read.

The Committee on a Memorial to Congress respecting the employment of Civil Engineers on National Public Works, asked through the Chairman, C. Macdonald, for an extension of the time for preparing the memorial, which was granted, and the date for the ballot on the memorial was fixed at January 5th, 1881.

Ballots were canvassed, and the following candidates were declared elected: As Members—Robert Ballard, of Queensland, Australia; John F. Barnard, of St. Joseph, Mo.; Redmond J. Brough, of Toronto, Canada; Cyrus B. Comstock, U. S. Army, Detroit, Mich.; James L. Frazier, of Morehead, Ky.; Robert B. Stanton, of Madisonville, O.

OF THE BOARD OF DIRECTION.

AUGUST 3d, 1880.—Applications for membership were considered. The Secretary and Treasurer presented list of members in arrears for dues, and Form C was ordered to be sent to all such. Appropriations were made. Leave of absence was granted to the Secretary for six weeks, and the Treasurer was requested to act as Secretary, *pro tem.* James B. Francis, Thomas C. Clarke and Charles Hermany were appointed Censors to award the Norman Medal.

DISCUSSION,

At the regular meeting held during the Annual Convention May 26th, 1880 (page 49, Proceedings, July, 1880), on

THE MODE OF ELECTING MEMBERS.

W. P. Shinn.—The fourth article of the Constitution, provides that civil, military, geological, mining and mechanical engineers, architects and other persons who by profession are interested in the advancement of science, shall be eligible for admission in their appropriate class. There are other sections which provide what the particular requirements are of eligibility to the position of member and of associate, respectively; and there is another section that provides that ballots shall be taken to decide whether or not the persons who are recommended as members of this Society shall be allowed to become members, and I take it, that under our Constitution, it is a right that belongs to every engineer described in this section to become a member of this Society in his appropriate class, if he comes within the description of this section, and of the other sections which describe the qualification for each class. Some two years ago I recommended to the membership of this Society a gentleman who has been for about thirty years a member of this profession, who has practiced in the various branches of the profession, but principally in the construction and management of railroads, during nearly the whole of that thirty years, and who has attained the position of general manager of a company controlling nearly a thousand miles of railroad; the application of that gentleman was brought before the Board of Direction, was considered by them, was approved by them, and his name was sent out to be balloted for. At that time our Constitution provided that three negative votes should exclude, and the gentleman received precisely three negative votes; they thought possibly there was some mistake, and a second ballot was had upon the same application, with the same result, there were precisely three negative votes. Recently, within the past two months, the name of this same gentleman has been again presented, and again balloted for, but the change in our Constitution having made it necessary for five negative votes to exclude, I understand there were six, and this gentleman was excluded from membership by six negative votes. Now, of course, every member of this Society has a right to cast a negative vote, and I take it that that right applies to negative votes cast for professional considerations, and not for social or merely unfriendly reasons; I do not know the names of the members who cast negative votes in the case, and I do not want to know them; I am told that the names are known, or are believed to be known, but I have no desire to know them; but it has appeared to me, and it has appeared to some other members of the Society with whom I have conversed upon the subject, and, indeed, my attention was called to the

matter by other members, that the reasons for the exclusion of that gentleman from membership were not professional reasons.
that to-day he is as fully entitled to membership of this Society as I am, and I know of no reason why he should not be a member of this Society; I know of no reason that comes within the prohibitions of our Constitution, and if, as has been thought, and indeed, alleged, that one or all of those negative votes were cast for social and personal reasons, an injustice has been done. First, to the gentleman against whom the ballot was cast; second, to the members of this Society who recommended that gentleman; and third, and worst of all, to the Society itself. This Society cannot afford to stand on so narrow a basis that any social or personal reasons can keep out of it any man whose professional attainments entitle him to membership. There are in every city of any size social clubs, and a gentleman has a perfect right to black-ball an applicant for social reasons; if he don't see proper to associate with the applicant it is his right to black-ball him; to say that he does not wish to meet him at the club; but I take it, Mr. President, this is no such place, and that no member in this Society has any right to cast a negative vote against any applicant for any reasons of that character. Now, my object in calling attention to this matter was not to find fault with those gentlemen who cast those negative votes, far otherwise; what I wished to do was, to call the attention of the Society to the fact that the votes cast against this applicant have indicated that our present mode of election is not satisfactory; that it is not going to answer for the future welfare of the Society. Probably the best point that can be taken against it is this, that at present there is nobody responsible for any one who is an applicant failing to become a member of this Society. The Board of Direction have tried, before the names of the applicants are brought up for ballot, to canvass the subject, to make such inquiries as they think proper, and if any member choose to write them, and state reasons why a person known to him to be an applicant should not become a member, the Board will undoubtedly take it into consideration, and after the Board has passed on the subject, and has decided, as far as they know, that an applicant is eligible, and is a proper person to be balloted for, then, if that person does not become a member, there is nobody responsible; the parties who say he shall not become a member are anonymous; you cannot put your finger on them; you cannot find out in any regular way what their reasons are, and as our Constitution now stands, you have no right to ask, and I submit, that that is not a safe foundation for us to rest upon. I propose, therefore, between this and the time of the next annual meeting, within the proper time, as required by the Constitution, to submit an amendment to the Constitution which shall provide in substance, that applications for membership shall go before the Board of Direction, and that a circular shall be issued by the Secretary, stating that at a certain meeting of the Board of Direction, at

least thirty days ahead, the application will be considered by the Board ; that the Board at that meeting shall decide whether or not that applicant shall become a member ; then all will know who is responsible if a proper man is rejected, while every member of the Society will have an opportunity to give the Board, through any of its members, any reasons of a professional nature which exist against the applicant becoming a member.

I would suggest, as one of the possibilities under the present state of our Constitution in regard to an election, that it is within the power of any five members of this Society now to say that this Society shall not have any more members ; I do not wish to say, or even to intimate, that there are any five members who would combine for that purpose, but I simply say it is in the power of any five, not only in their power, but, as far as the forms of our Constitution are concerned, it would seem to be their right, although I claim that that is not the fact ; that on the other hand, I believe an applicant, if he is eligible, and has the proper qualifications professionally, has a right to be a member of this Society. I wish to bring the subject before this large Convention, in order that when the amendment to the Constitution is presented, that members will all understand its bearing ; that it is not brought up now with any reference to the particular person who has thrice been rejected by the Society ; that case is the text that has called attention to the subject, and, as I believe myself, as well as some other members with whom I have conversed, we are not on the right path ; we must retrace our steps.

I will say right here that I urged most strongly the adoption of the present mode of balloting for applicants, but I have repented. I believe it was a mistake, and I propose to signify my repentance by offering the amendment to the Constitution I refer to.

C. Shaler Smith.—I would state in relation to what Mr. Shinn has so well stated, the evil has been larger probably, and of a greater extent, than perhaps we are aware of ; I have in my hand a letter from a member in New York who, in speaking of questions to be brought up before this meeting, states : "Then another question which should be discussed is the matter of admission of members ; it is well known that a clique has been formed to prevent the admission of members, to black-ball certain prominent members well worthy of admission into the Society, because of personal antipathy, etc." This comes from New York ; I learn to-day also from a member from Cincinnati, that a similar case has occurred there, where a man thoroughly well known and thoroughly fit for admission to the Society, has been black-balled in a similar manner.

Like Mr. Shinn, I was one of those who strongly advocated the present mode, but I think the best method of correcting the present evil is this, no man having a desire to black-ball a member of this Society

should be afraid to acknowledge that fact, and over his own signature give his reasons therefor. I think the Constitution should take this shape ; allow the ballot to stand as it is, and provide in the amendment to the Constitution that members desiring to black-ball shall, over their own signature, give their reasons for so doing ; and then, that the Board of Direction shall correspond with those members, and ascertain the facts or data that they have to give in investigating the question, and if, in their own opinion, the charges are not sustained, that the black-balls be thrown out, and considered as a vote not cast ; I believe that will give us a solution of the question, and enable the Board of Direction to get at the root of the question, and find whether the charges which may be made against any member are made in good faith.

J. J. R. Croes.—Before the discussion goes any further, it may be as well to correct a misapprehension under which the gentleman who has just spoken seems to labor. He states that the letter from which he read was received from New York ; in that letter it is stated : "It is well known that a clique had been formed to prevent the election of certain prominent engineers." I have been in communication with a great many members, and I hear a great deal that goes on in the Society, and I have never heard anything of such a thing except in connection with the two members who were black-balled, or for whom negative votes were cast in the April or March meeting. I think there have been no candidates black-balled for more than two years, with the exception of those two, and one other case, and that other one I have heard no more about. I know there were five negative votes, and the matter dropped; but I do not believe there is any clique formed to prevent the admission of certain men at all, and I would want better evidence than a letter of that kind to convince me of it ; I do not believe the members of the Society would form such cliques. As Mr. Shinn has stated, one gentleman was rejected twice, two years together, and the manner of electing was changed then—and it was his rejection that caused that change—and when he was nominated again he got six black-balls. Now, if the Board of Direction should reject any member, is the Board of Direction to be changed because they find persons objectionable ? The fact is, that there has been a large number of members voted for and elected, I think over one hundred within three years, and only three have been rejected, and I do not think that looks very much as if there was any clique formed.

I do not want to be understood as opposing any change in the mode of election ; it is very probable that some better mode than the present one might be devised. I only doubt the correctness of the assertion that well known combinations have been formed to prevent the election of members. I do not believe that to be the case.

William Metcalf.*—It seems to me that the "black-ball" feature in elections for members should not be abolished. If the Society is to

* By letter, June 24, 1880.

retain a professional character, it will be necessary to throw some safeguard around the question of admission to membership; and, on the other hand, if the Society is to be national in character, which I suppose we all wish it to remain, it is equally clear that any person of good character who shall have attained sufficient standing in his profession to meet the requirements of the Constitution and By-Laws, has then a right to become a member, upon application in due form. The Society should be able to protect itself against the admission of persons of insufficient experience, or of bad character, such as dishonesty, unfaithfulness, unprofessional conduct of any kind, or gross immorality of any sort, that might bring discredit upon the profession, or be seriously repugnant to the idea of personal association to decent members.

On the other hand, it is belittling to the Society when any members use the negative vote to exclude an eligible candidate from any motives of personal spite or spleen, and some of us are compelled to believe that such mean use has been made of a power which was only intended as a professional safeguard.

I would suggest as a remedy, that one negative vote should be sufficient to exclude when accompanied by a written statement of the reasons for such a vote, and indicating the means by which the Board of Direction could verify such statement. The statement, of course, would require no signature, coming as it would under cover with a letter ballot.

The course of the Board of Direction should then be as follows :

First.—It should be obligatory upon the Board to ascertain whether the charges were true or not.

Second.—It should be discretionary with the Board to decide whether the charges were proven, and, if proven, whether they were sufficient to justify exclusion under the laws of the society.

Third.—All such statements, examinations and decisions should be inviolably secret. It is certainly no function of the society to announce to the world its own sanctity, or the want of virtue in others.

Fourth.—No negative vote unaccompanied by a statement of the reasons for such vote, should be counted against a candidate, unless a majority of all the votes cast should be negative; in case of such serious opposition, we, as good Americans, ought to submit to the will of the majority.

I have not put these suggestions in the shape of formal resolutions, because I do not know just how the question stands before the Society; but I wish you would lay them before the Society in some shape as a discussion of the question.

I believe we ought to guard the matter of membership carefully, and I think we ought to be able to trust our Board of Direction, and to invest them with authority to see that a wise provision of our laws is not abused for the gratification of personal ill feelings, in which the members as a whole can have no possible interest.

MEMOIRS OF DECEASED MEMBERS.

ARTHUR LIVERMORE FORD,* Assoc. Member, A. S. C. E.

DIED MAY 30TH, 1880.

Arthur Livermore Ford was born at Plymouth, New Hampshire, on January 4th, 1851. Mr. Ford's professional work ended too soon and too abruptly to leave many evidences of the skill and judgment of which those who knew him best believed him to be capable. His preparation for practical work was unusually elaborate. While a boy he had formed the habit of close application to study, which he always retained. His memory was a rare one, enabling him to repeat, verbatim, half a dozen pages of a book, after having read them rapidly twice, and a year afterward he would remember them with substantial accuracy. He worked earnestly and continuously to make this faculty of service by mastering the principal modern languages, and acquiring a thorough knowledge of their engineering and general literature. The retentive quality of his memory made his acquisitions as lasting as they were rapid. He was a good chemist, geologist and mineralogist, and his manliness and frankness not only prevented his ever claiming more knowledge than he possessed, but always led him to give the limits of his information at once. With great zeal for general culture, he was too earnest to be a *dilletante:* a man of enthusiasm and imagination, he, nevertheless, maintained an admirable poise and acted deliberately.

After completing, in 1870, the "special course" at Columbia College School of Mines—the institution at that time having no regular civil engineering course—he spent the summer and fall of that year as mineralogist in Professor Hayden's geological survey of Wyoming Territory. In 1871 he was assistant to Professor Egleston, at the School of Mines, making the drawings for his work on Crystallography.

From 1871 to 1877 he was successively employed as transit-man on a Brooklyn township survey; assistant engineer on the hydrographic survey of Passaic river, under Mr. Walter Brinkerhoff, assistant to General Newton; assistant engineer in charge of party on topographic survey of Long Island City, under Mr. George S. Greene, Jr.; transit-man on the Saddle River Railroad Survey, under Mr. E. P. North; on surveys under Mr. M. J. Becker, Chief Engineer, Pittsburgh, Cincinnati and St. Louis Railway; assistant in charge of surveys for 30 miles of the Chesapeake and Ohio Canal Extension, under Col. Wm. E. Merrill; engineer in charge of construction of 15 miles of the Lake Shore branch of the Rome, Watertown and Ogdensburg Railroad, and of a portion of the road through the City of Oswego; and assistant engineer in charge

* Committee to prepare memoir, M. N. Forney, O. Chanute, C. MacDonald.

of building crib-work for Little Sodus Harbor Breakwater, under Major W. McFarland. In November, 1877, Mr. Ford went to Cuba and built the Zaza (narrow gauge) Railroad, and afterward spent some time in Havana on various engineering and architectural works.

It was here that he conceived the idea of devoting himself especially to Spanish-American engineering work, a field for which his extraordinary facility in using the language and ready adaptability eminently fitted him. His subsequent experience, in 1879, as an engineer on the location and construction of the Nicaraguan Government railroad confirmed him in his determination, and those who knew him believed that with his singular tact, persistent energy and rugged health he had a career of unusual promise before him.

In March of the present year he sailed for Aspinwall to reconstruct the foundation of the Chagres River Bridge of the Panama Railroad, which had been destroyed by the floods last fall. He had nearly finished this work, and had so far completed negotiations for a considerable contract in one of the South American countries that he expected to go there as soon as he could leave the bridge, when he was attacked by the fever prevailing at Aspinwall. His last act, when he knew death was inevitable—that of writing a letter to his father, expressing wishes to be carried out—was done with characteristic coolness and orderliness.

Mr. Ford's tastes and manners were such as are usually ascribed to "gentlemen of the old school." He was absolutely pure. He had the utmost abhorrence for every form of wrong or dishonesty. It seemed that no disguise could make such things alluring to him. Unusually ready in conversation, aided by his wit and unerring memory, he expressed himself with force, and yet always with such tact and modesty that he made few enemies. He had many friends, and these by no means limited to those of his own age. Few young men had more or warmer friends than he among older men.

His death is still so recent, and was so shockingly sudden, that those who loved him most can now hardly think of it with composure; and yet they find a singular comfort in recalling the loveable qualities which will make him live forever in their memories.

ANNOUNCEMENTS.

The next regular meeting of the Society will be held on Wednesday, September 15th, at 8 P. M. Discussion will be had of papers previously read.

A regular meeting of the Society will be held on Wednesday, October 6, 1880, at 8 P. M.

Proposed amendments to the Constitution must be submitted in writing, signed by not less than five members, at or before this meeting, in order to be acted upon this year.

The Nominating Committee will present, on or before the first day of October, the names of the persons selected by them as candidates for officers for the year beginning November 3d, 1880, to be voted for on November 3d.

It is provided by the 5th section of the 24th By-Law, that in addition, any five members may present to the Board of Direction, on or before October 1st, a list of names proposed by them for officers, which list shall also be issued for ballot.

The Committee on Gauging of Streams requests measurements of flood discharge of streams, and also of discharge in periods of great dryness. It is very desirable that statements of the drainage area above the point of measurement should accompany such data.

A classified catalogue of the Library of the Society is in course of preparation, and the first part, comprising titles relating to Railroads, is now in the printer's hands, and will be issued about October 1st. It is hoped that the publication of this catalogue will result in large additions to the Library, especially of reports of companies of which partial files are now in our possession.

Lieut. Commander Gorringe, U. S. N., has promised to lay before the Society an account of the methods employed in the removal of the Alexandrian Obelisk to this country, as soon as his engagements will permit. Due notice will be given of the date of the presentation of his remarks.

The following resolutions were adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications :

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of the differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door east from Fourth avenue, and near the southwest corner of Grammercy Park. It is open from nine o'clock A.M. to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P.M.

The Library and Conversation Rooms will also, for the present, be open every *Wednesday evening* from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Wednesday evenings both for consultation of books and periodicals and for conversation.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Administration des Ponts et Chausees, Paris:

Annalen. June and July, 1880.

From American Academy of Arts and Sciences, Washington, D. C.:

Proceedings. Vol. VII. New Series. Part II. December, 1879, to May, 1880.

From American Gas-Light Association, Wm. Henry White, Secretary, New York :

Report of Proceedings of the Annual Meetings held in Cincinnati, Oct. 17, 1877, and in New York City, Oct. 15, 1878.

From American Iron and Steel Association, James M. Swank, Secretary, Philadelphia:

Tracts issued by the Association, as follows :

Our Foreign Commerce.

A Tariff is not a Tax. Giles B. Stebbins.

Free Trade and Protection. Hon. John Welsh.

Short Essays on Protection. David H. Mason.

Who are Benefited by Protection?

What Protection has done for the United States. Hon. Thomas H. Dudley

The "Barbarism of Protection." An

open letter to John Bright. Augustus T. Freed.
Who is Augustus Mongredien?

From Boston Public Library, Mellen Chamberlain, Librarian, Boston :
Twenty-eighth Annual Report of the Library.
Bulletin of the Library. July, 1880.

From Robert Briggs, Philadelphia:
Report on the Plans for Warming and Ventilating the Bridgeport (Conn.) School House. Rob't Briggs (6 copies.)

From Hon. Allan Campbell, Commissioner of Public Works, New York :
Report of the Department of Public Works, Quarter ending March 31, 1880.

From Bureau of Statistics and Geology of Indiana, John Collet, Chief, Indianapolis :
First Annual Report of the Department of Statistics and Geology of the State of Indiana.

From Frank Doherty, Columbus, Ohio:
Tenth Annual Report of the Trustees of the Water Works of Columbus.

From Engineers' Club of Philadelphia, Howard Murphy, Cor. Secretary, Philadelphia :
Proceedings. Vol. 1. No. 5.

From Engineers' Society of Western Pennsylvania, James H. Harlow, Secretary, Pittsburg :
Use of Steel in Construction. Albert F. Hill, C. E.

From Charles E. Fowler, New Haven, Conn.:
Annual Reports of the Street Department of New Haven for 1879.

From Albert F. Hill, New York :
Use of Steel in Construction. Albert F. Hill, C. E.

From Institution of Civil Engineers, James Forrest, Secretary, London:
Minutes of Proceedings. Vol. LX.
The Main Drainage of Torquay. George Chatterton.
The Purification of Gas. Harry E. Jones.
The Chile Vein Gold Works, South America. George Attwood.
Explosive Agents applied to Industrial Purposes. Frederic A. Abel, C. B. F. R. S.
Cleopatra's Needle. Benjamin Baker.
Note on a New Snow Plow. John Newman.
The Caledonian Railway Viaduct over the River Clyde at Glasgow. Benjamin H. Blyth.
The Calder Viaduct on Wishaw Line of the Caledonian Railway. David M. Westland
Note on the São Francisco River, Brazil. W. Milnor Roberts.
The Removal of Sunken Rocks in Brest Harbor. H. Willotte.
Abington Sewerage. Charles F. Gower.
The Temnograph. Alexander M. Rymer Jones.
Rural Water Supply. Thomas S. Stooke.

From Baltasar Munoz Lumbier, Mexico:
Lós Aerólitas de Chihuahua. Baltasar Munoz Lumbier, Mexico, 1880.

From New York Meteorological Observatory, Daniel Draper, Director, Central Park, New York:
Abstracts of Registers from Self-Recording Instruments. June and July, 1880.

From Wm. Ripley Nichols, Boston:
Papers on Water Supply. Prof. Wm. Ripley Nichols. Boston, 1880.

From Edward P. North, New York:
Remonstrance against the removal of the Murray Hill Reservoir. New York, 1880.
Seventh Annual Report of the Water Commissioners of the Village of Saratoga Springs. Saratoga Springs, 1880.
Twelfth Annual Report Nassau Water Department. Brooklyn, 1872.

From Henry V. Poor, New York :
Manual of the Railroads of the United States for 1880. Henry V. Poor.

From Ernest Pontzen, Paris :
Chemin de fer de l'Arlberg. M. E. Pontzen, Paris, 1880.

From Publishers Revue Générale des Chemins de fer, Edgar Monjean, Secretary, Paris :
Revue Générale des Chemins de fer. May, 1880.

From Col. W. Milnor Roberts, Rio de Janeiro, Brazil :
Abstract of the report of the Hydraulic Commission of Brazil upon the examinations of the São Francisco River. W. Milnor Roberts, New York, 1880.

From Royal Technical School, Hanover, Germany :
Catalogue of the School, 1880–81. (German.)

From Royal United Service Institution, Capt. B. Burgess, Secretary, London:
Journal of the Institution. Vol. XXIV. No. 105.
Contents Vol. XXIII.
Proceedings 49th Anniversary Meeting.

From George P. Rowell & Co., New York :
American Newspaper Directory. New York, 1880.

From Hon. Horatio Seymour, Jr., Albany, N. Y.:
Annual Report of the State Engineer and Surveyor on the Canals of the State of New York for 1880.

From Société des Ingenieurs Civils, M. Mallet, Secretary, Paris :
Memoires. May and June, 1880.

From State Board of Health of Massachusetts, Charles F. Folsom, M. D., Secretary, Boston :
Eleventh Report of the State Board of Health. Index Vols. I–XI. F. H. Brown, M. D., Boston, 1879.

From John C. Trautwine, Philadelphia:
The Civil Engineers' Pocket Book. J. C. Trautwine, Philadelphia, 1880.

From J. Nelson Tubbs, Rochester, N. Y.:
Annual Report of the Executive Board and Water Works and Fire Board. Rochester, N. Y., 1880.

From United States Coast Survey, Washington, D. C.:
Report of U. S. Coast Survey for 1876. Washington, 1879.

From United States Light-house Board, Washington, D. C.:
List of Beacons, Buoys, Towers and other Day-Marks, in the Fifth Light-house District. Corrected to May 1, 1880.

From Capt. George M. Wheeler, Corps of Engineers, U. S. A., Washington, D. C.:

Five Volumes. Geographical Surveys West of the 100th Meridian.
Volume II. Astronomy and Barometric Hypsometry.
Volume III. Geology.
Volume IV. Paleontology.
Volume V. Zoölogy.
Volume VI. Botany.

From Engineer Department, U. S A., Gen. Horatio G. Wright, Chief of Engineers, Washington, D. C.:

A Report from the Chief of Engineers urging the necessity for completion of the office work connected with the surveys of the 100th Meridian, under charge of Capt. George M. Wheeler, and recommending an appropriation therefor.
A Letter from the Chief of Engineers covering copy of report from Maj. F. Harwood, upon a resurvey of the Bar at the mouth of Bell River, Mich., made in compliance with law.
A Letter from the Chief of Engineers and accompanying report of Maj. F. Harwood, upon the resurvey of Clinton Run, Mich.
A copy of a Report of the results of a Survey of the Illinois River. Maj. G. J. Lydecker.
A Telegram from Gen. Q. A. Gillmore, President of the Mississippi River Commission, recommending that the estimate heretofore submitted for surveys and expenses of the Commission be increased.
Papers showing maintenance of the Channel at the South Pass Jetties, Mississippi River, for quarter ending May 9, 1880.
A Letter from the Chief of Engineers submitting copy of report of Gen. John Newton, "in relation to the port and harbor of New York, and the waters near the same."
A Letter from the Chief of Engineers covering copy of report of Gen. Q. A. Gillmore, and accompanying map, upon an examination of Port Royal River, Beaufort, S. C.
Report of the results of an examination made of the Peninsula of Florida, with a view to the construction of a Ship Canal from St. Mary's River to the Gulf of Mexico. Gen. Q. A. Gillmore.
A Letter from the Chief of Engineers covering copy of report of Col. C. S. Stewart upon an examination of Trinidad Harbor, Cal., made in compliance with law.
Specifications for dredging in Tubee Channel, Maine. Gen. Geo. Thom.
Specifications for the excavation of Sunken Ledge at the Gut, opposite Bath, Me. Gen. Geo. Thom.
Specifications for furnishing Rubble Stone for the Breakwater at Richmond's Island, Maine. Gen. Geo. Thom.
Specifications for the removal of Sunken Ledge and furnishing Rubble Stone in Portsmouth Harbor, N. H. Gen. Geo. Thom.
Specifications for the Dredging in Lake Winnipiseogee, N. H. Gen. Geo. Thom.
Proposals for River and Harbor Improvements in Maine, New Hampshire and Massachusetts. Gen. Geo. Thom.
Specifications for the Dredging in Boston Harbor, Massachusetts. Gen. Geo. Thom.
Specifications for the Dredging of Plymouth Harbor, Mass. Gen. Geo. Thom.
Specifications for Excavation in Taunton River, Mass. Gen. G. K. Warren.
Specifications for Excavation in Block Island Harbor, R. I. Gen. G. K. Warren.
Specifications for Excavation in Providence River, R. I. Gen. G. K. Warren.
Specifications for Excavation in Connecticut River, Conn. Gen. G. K. Warren.
Specifications for Rip-Rap Granite for Jetties at mouth of Connecticut River, Conn. Gen. G. K. Warren.
Specifications for Excavation in Little Narragansett Bay, Rhode Island and Connecticut. Gen. G. K. Warren.
Specifications relating to the Deepening of the Channel leading to the Port of Havre de Grace, Md. Maj. W. P. Craighill.
Advertisement, Instructions, Specifications, Proposals and Bidder's Bonds for improving Calumet Harbor, Ill. Maj. G. J. Lydecker.
Advertisement, Instructions, Specifications, Proposals and Bidder's Bonds for improving Chicago Harbor, Ill. Maj. G. J. Lydecker.
Specifications relating to the Construction of Jetties at Sullivan's Island, S. C. Gen. Q. A. Gillmore.
Advertisement, Instructions, Specifications and Proposals for improving "The Narrows" of Sabine River, Texas. Maj. S. M. Mansfield.

From Gen. William W. Wright, Philadelphia:

Report on the Survey of the Alleghany Valley Railroad. W. Milnor Roberts. Pittsburgh, 1853.
Reports of Superintendent and Engineer of the Alleghany Portage Railroad for year ending November 30, 1853.
Third Report of the Alleghany Railroad and Coal Co. Philadelphia, 1855.
Report of the President, Directors and Chief Engineer of the Alabama and Tennessee River Railroad at the Second Annual Meeting of the Stockholders, November 18, 1851.
Report of the Chief Engineer of the Bellefontaine and Indiana Railroad Co. W. Milnor Roberts. Sidney, Ohio, 1851.
Second Semi-Annual Report of Pittsburgh, Fort Wayne and Chicago Railroad. Pittsburgh, 1859.
First Report of the Fort Wayne, Lacon and Platte Valley Air-Line Railroad Co. November 10, 1853.
Documents of Controversy between Canal Commissioners of Pennsylvania and the Harrisburg and Lancaster and Pennsylvania Railroad Co. Philadelphia, 1852.
Second Annual Report of the Lancaster, Lebanon and Pine Grove Railroad Co. Philadelphia, 1854.
Ninth Annual Report of the Little Miami Railroad Co. for 1851.
Report of the Chief Engineer upon Survey, Location and probable Cost of the Northeast and Southwest Alabama Railroad. E. D. Sanford. Tuscaloosa, Ala., 1855.
First Annual Report of the Marietta and Cincinnati Railroad Co. Philadelphia, 1851.
First Annual Report of the Chief Engineer of the Memphis and Charleston Railroad. Charles F. M. Garnett. Huntsville, 1851.
Third Annual Meeting of the Stockholders of the Memphis and Charleston Railroad Co., with Reports of Directors, Chief Engineer and Superintendents. Huntsville, 1853.
Fifth, Seventh and Ninth Annual Reports of

the Memphis and Charleston Railroad Co. Memphis, 1855, 1857 and 1859.

Exhibit of the Affairs of the Memphis and Charleston Railroad Co. Memphis, 1854.

Summary of Proceedings of the Convention of the Stockholders of the Memphis and Charleston Railroad Co., held at Tuscumbia, Ala., April 3, 1854.

A compilation of the Acts of the Legislatures of Tennessee, Alabama and Mississippi, in relation to the Memphis and Charleston and La Grange and Memphis Railroad Cos, Memphis, 1852.

Seventh Annual Report of the Nashville and Chattanooga Railroad Co. Nashville, 1855.

Report in regard to the Western Extension of the New York and Erie Railroad. New York, 1856.

Report of the Chief Engineer of the Norristown and Freemansburg Railroad Co. L. E. Corson. Norristown, 1853.

Map of the North Pennsylvania Railroad and its connections. 1853.

North Pennsylvania Railroad to connect Philadelphia with North Pennsylvania, Western New York, the Lakes and Canada West. Philadelphia, 1853.

Second Report of the North Western Railroad Co. Philadelphia, 1855.

Second Report of the Ohio and Pennsylvania Railroad Co. Solomon W. Roberts. Philadelphia, 1850.

Sixth Annual Report of the Ohio and Pennsylvania Railroad Co. January 24, 1854.

Exhibit explanatory of the seven per cent. special mortgage convertible Bridge Bonds of the Ohio and Pennsylvania Railroad Co. Philadelphia, 1856.

Report on the Ohio and Indiana and Fort Wayne and Chicago Railroad, March 5, 1856. W. H. Wilson.

Report of the Philadelphia and Reading Railroad Co. January 14, 1856.

Report of the Superintendent of the Philadelphia and Columbia Railroad. November 30, 1854.

Organization for conducting the business of the Pennsylvania Railroad. Philadelphia, 1852.

By-Laws and Charter of the Pensylvania Railroad Co., and its Supplements. Philadelphia, 1853.

Charter and Supplements of the Pennsylvania Railroad Co., with By-Laws of the Board of Directors. Philadelphia, 1859.

First Annual Report of the Chief Engineer of the Pennsylvania Railroad Co. J. Edgar Thompson. Philadelphia, 1848.

First, Third, Fourth, Fifth, Sixth, Seventh, Eighth, Ninth and Thirteenth Annual Reports of the Pennsylvania Railroad Co. for 1847, 1849, 1850, 1852, 1853, 1854, 1855, 1856 and 1860.

Report of H. Haupt, Chief Engineer Pennsylvania Railroad Co., with a communication from the President of the Ohio and Pennsylvania Railroad Co. on the expediency of aiding the Ohio and Indiana and the Fort Wayne and Chicago Railroad Cos. to complete their roads. Philadelphia, 1854.

Reasons of the Board of Directors of the Pennsylvania Railroad Co. for declining to offer to purchase the main Line of the State Works. Philadelphia, 1854.

Robert Wightman *versus* Pennsylvania Railroad Co. 1854.

Will the Interests of Pennsylvania be advanced or the Revenue increased by continuing the tonnage tax upon the Pennsylvania Railroad?

Is a Tax upon the through tonnage Constitutional?

Laws relating to the Pittsburgh and Connellsville Railroad Co. Pittsburgh, 1853.

Annual Report of the Pittsburgh and Connellsville Railroad Co. for 1853.

Second Annual Report of the Pittsburgh and Steubenville Railroad Co. Pittsburgh, 1853.

Proceedings of the Stockholders of the South Carolina Railroad Co. and of the Southwestern Railroad Bank, at their Annual Meetings, Feb. 10, 11 and 12, 1852, Feb. 8 and 9, 1853, and Feb. 14 and 15, 1854.

Proceedings of the Southern Railroad Convention. Savannah, 1855.

By-Laws of Board of Managers of the Sunbury and Erie Railroad Co. Philadelphia, 1852.

Report of the President and Board of Managers of the Sunbury and Erie Railroad Co. Feb. 14, 1853.

Report of the final location of the Southern Railroad from Brandon, Miss., to the Alabama Line, in the direction of Charleston and Savannah. H. Haupt. Philadelphia, 1853.

Semi-Annual Report of the South Carolina Canal and Railroad Co. January 18, 1840.

Report of Survey for the Tyrone, Clearfield and Erie Railroad. James E. Montgomery. Clearfield, 1854.

Proceedings of the Stockholders of the Wilmington and Man. Railroad Co. January 24, 1855.

Report of the Superintendent and Treasurer of the Western and Atlantic Railroad to His Excellency Herschel V. Johnson. Sept. 30, 1855.

Report of a Survey of a Line of Railroad between the City of Cordova and some other point on the River Paraná, Argentine Confederation. Allan Campbell. London, 1857.

On the Railway Connections of Philadelphia with the Central West. Letters of Prof. Edward D. Mansfield of Cincinnati to Job R. Tyson, Esq., LL.D., of Philadelphia. Philadelphia, 1853.

Letter on the Improvement of the Alabama and Mobile River to John J. Walker, Esq., President Mobile Chamber of Commerce. Albert Stein. Mobile, 1856.

First Annual Report of the Clearfield Coal and Lumber Co. Philadelphia, 1856.

Constitutional Liberty. M. Le Comte de Montalembert. London, 1855.

The Geodesy of Britain; or, the Ordnance Survey of England, Scotland and Ireland. Adelos. London, 1859.

Address on the Life and Character of Humboldt. Alfred Stillé, M. D. Philadelphia, 1859.

Fourteenth Annual Report of the Monongahela Navigation Co. Pittsburgh, 1854.

An Act to incorporate the Ohio River Improvement Co. Philadelphia, 1855.

Cost, Revenue and Expenditure of the Public Works of Pennsylvania. Harrisburg, 1854.

European and Asiatic Intercourse *via* British Columbia by means of a Main Through Trunk Railway from the Atlantic to the Pacific. London, 1858.

Alleghany Bituminous Coal. L. Pusey, 1856.

THE NORMAN MEDAL.

CODE OF RULES FOR ITS AWARD.

I.—Competition for the Norman Medal of the American Society of Civil Engineers shall be restricted to Members of the Society.

II.—There shall be one gold medal, and only one, struck for each and every fiscal year of the Society, and awarded as hereinafter provided. The dies therefor shall be with the Superintendent of the United States Mint at Philadelphia, in trust exclusively for the above purpose. Such medal shall be of a cost equal to the annual interest received upon $1 000 of the Consolidated Stock of the City of New York, Certificate No. 179, of the additional new Croton Aqueduct Stock of the City of New York, authorized by an Act of the Legislature of the State of New York, Chap. 230, passed April 15th, 1870, dated November 17th, 1873, now held in trust by the Treasurer of this Society, and so held solely for this purpose, and shall be executed upon his order.

III.—All original papers presented to the Society by members of any class, during the year for which the medal is awarded, shall be open to the awards, provided that such papers shall not have been previously contributed in whole or in part to any other association, nor have appeared in print prior to their publication by the Society, nor have been presented to the Society in any previous year.

IV.—The Board of Censors to award the Medal shall consist of three members of the Society, to be designated by the Board of Direction. The Secretary of the Society shall act as Secretary to the Board of Censors.

V.—The medal shall be awarded to such paper as the said Board shall judge to be worthy of special commendation for its merits as a contribution to Engineering Science, not merely relatively as compared with others presented during the same year, but as exhibiting the science, talent or industry displayed in the consideration of the subject treated of, and for the good which may be expected to result from the discussion and the inquiry.

VI.—In case no paper presented during the year shall be deemed of sufficient value to receive an award, the amount of the interest of the fund for that year shall be expended by the Board of Direction in the purchase of books, to be offered as a premium for the second best paper in the next year in which more than one paper of sufficient value may be presented.

VII.—The medal year shall terminate on the first day of August, and the award shall be announced at the Annual Meeting in November.

VIII.—The Treasurer of this Society shall cause the medal to be prepared and delivered to, or deposited to the order of, the successful competitor, within two months after the Annual Meeting at which the same shall have been awarded.

LIST OF MEMBERS.

ADDITIONS.

MEMBER.

Date of Election.

LEACH, SMITH S.....U. S. Ass't. Engineer, 2828 Washington Ave., St. Louis, Mo.....July 7, 1880.

MCNULTY, GEORGE W....Ass't. Engineer, East River Bridge, 21 Water St., Brooklyn, N. Y.....May 5, 1880.

CHANGES AND CORRECTIONS.

BURR, JAMES D.....(Lantry & Burr), Topeka, Kansas.

EARLEY, JOHN E.....Locating Engineer, R. G. M. & P. RR., Pueblo, Col.

FINK, RUDOLPH.....Gen. Manager Selma, Rome & Dalton Railroad, Selma, Ala.

ROCKWELL, SAMUEL.....P. O. Box J., Kansas City, Mo.

RESIGNATION.

BENDER, CHARLES..... August 11, 1880.

DEATHS.

HAYWARD, JAMES A.....Elected Member, September 5, 1877. Died August 13, 1880.

GREENWOOD, WILLIAM H Elected Member, March 3, 1880. Died August 29, 1880.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VI.—October, 1880.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

SEPTEMBER 15TH, 1880.—The Society met at 8 P. M., Vice-President Chanute in the chair.

The death of William H. Greenwood, Member A. S. C. E., was announced.

A discussion on Inter-Oceanic Canals, by A. G. Menocal, Member A. S. C. E., was read, and the discussion was continued by Messrs. Shelbourne and Welch.

OCTOBER 6TH, 1880.—The Society met at 8 P. M., Vice-President Chanute in the chair.

Ballots were canvassed, and George Hume Simpson, of Terre Haute, Ind., and William Williams Walker, of Hannibal, Mo., were declared elected as Members.

A communication from the Board of Direction, suggesting arrangements for the approaching Annual Meeting, was read, and the suggestions formally approved. These are as follows: That as the day of the Annual Meeting, November 3d, is the day after the National election, it will not be convenient for non-resident members to attend. It is suggested, therefore, that the following arrangements be made:

The Annual Meeting to be called to order at 10 A. M., November 3d; Tellers appointed to canvass the votes for officers, Report of the Board of Direction presented and ordered printed, and a recess taken until 8 P. M.

In the evening the report of the Tellers of the votes to be presented, and a recess to be taken until November 17th, at 10 A. M.

The Annual Meeting to be resumed at 10 A. M., November 17th, as a business meeting for discussion on reports, constitutional amendments and other business. In the evening at eight, a public meeting for pro-

fessional discussion only with special paper on a subject to be announced. The evening meeting to be followed by a collation. On November 18th, the resident members to arrange for either an excursion to points of interest or a discussion on some professional subject; the arrangements to provide also for the evening of this day.

The following proposed amendments to the constitution were regularly submitted. These amendments will be in order for discussion and amendment at the Annual Meeting, and will afterwards be voted upon by letter ballot:

As to Election of Honorary Members.

Proposed amendment to Article XXIII.

Strike out the words, "and the Past Presidents of the Society," and insert "such Past Presidents of the Society as shall be at the time members of the Society and resident in the United States."

As to Time of Annual Meeting, etc.

Proposed amendment to Article XXII.

For "first Wednesday in November," read "first day of January."

Proposed Amendment to Article XXX.

The Article to read:

The Annual Meeting for the election of officers and hearing the Annual Reports shall be held on the third Wednesday of January. The Board of Direction shall lay before the meeting a report of the state of the Society, together with a statement of the Treasurer, verified by the Committee on Finance, of the funds of the Society, and the receipts and payments during the year ending on the 31st of December preceding.

Proposed Amendment to Article XXXI.

The Article to read:

The annual contributions shall become due for the ensuing year on the first day of January, and shall be payable in advance. It shall be the duty of the Secretary to notify each member of the amount due for the ensuing year at the time of giving notice of the Annual Meeting. Members in arrears for the dues of the current year shall not be allowed to vote at the Annual Meeting.

Proposed Amendment to Article V.

After the words "Annual Meeting of the Society," strike out the words, "and shall hold their offices until others are elected," and insert, "The term of office shall begin at the close of the Annual Meeting, and continue for one year, or until other officers are elected."

A letter from Professor R. H. Thurston, Member A. S. C. E., Secretary of the late United States Board to test iron, steel and other metals, was read. [See Announcements below.]

A paper by A. G. Menocal, Member A. S. C. E., giving additiona information obtained by recent surveys in Nicauragua, was read by the Secretary, and discussed by Messrs. Chanute, G. S. Greene, T. P. Kinsley and L. B. Ward.

ANNOUNCEMENTS.

THE ANNUAL MEETING will be held Wednesday, November 3d, 1880, at 10 A. M. As arranged at the meeting of October 6th (see minutes on page 83 preceding), a recess will be taken to November 17th, when the Annual Meeting will be resumed, in order to give members unable to attend on the former date an opportunity to be present The arrangements for the meeting will be made by the members resident in New York, and will extend over the days and evenings both of November 17th and November 18th.

THE SECOND REPORT OF THE LATE UNITED STATES BOARD TO TEST IRON, STEEL AND OTHER METALS will soon be issued. The following letter is published for the information of members:

STEVENS INSTITUTE OF TECHNOLOGY.
DEPARTMENT OF ENGINEERING.
HOBOKEN, Sept. 1st, 1880.

JOHN BOGART, Esq.,
Sec. Am. Society of Civil Engineers,
New York City:

DEAR SIR,—The second report of the late "United States Board, appointed to test iron steel and other metals," is now going through the press, and will probably be ready at the meeting of Congress, or somewhat later in the winter.

Members of the Society wishing copies should apply to members of Congress at once.

The whole edition of the first report was taken up before many members of our Society had learned that it was published.

It is probable that a properly directed effort might secure its re-publication.

Very truly yours,
R. H. THURSTON,
Sec. late Board, &c.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Administration des Ponts et Chaussées, Paris:
Annales. August, 1880.

From American Chemical Society. P. Casamajor, Secretary, New York:
Proceedings. July, 1880.

From American Society of Mechanical Engineers, New York:
List of Officers, Members and Rules. Organized April 7, 1880.

From Edward R. Andrews, New York:
Creosoting Timber. Preserved Crossties. A reprint from the *Railroad Gazette.* Vol. XII. No. 21. (Copies for distribution,)

From Argentine Scientific Society, Don Eduardo Aguirie, Secretary, Buenos Ayres:
Anales. July and August, 1880.

From E. W. Bowditch, Boston;
Paper on the Drainage of Summer Hotels and Country Boarding Houses. E. W. Bowditch, Boston, 1880.

From Robert Briggs, Philadelphia:
The Absolute Economy of Electric Lighting. Robert Briggs. Philadelphia, 1880. (5 copies.)

From Bureau of Education, Washington, D. C.:
Proceedings of the Department of Superintendence of the National Education Association at its meeting at Washington, D. C., Feb. 18-20, 1880.
Circulars issued by the Bureau, as follows:
Legal Rights of Children.
Progress of Western Education in China and Siam.
The Indian School at Carlisle Barrack.
Vacation Colonies for Sickly School Children.

From O. Chanute, New York:

Argument before the Committee on Commerce of the U. S. Senate in opposition to the Reagan Bill for regulation of Inter-State Commerce by Railway. Feb. 11, 1879. G. R. Blanchard. New York, 1879.

Testimony of George R. Blanchard before the Special Railroad Committee of the New York Assembly. New York, 1880.

Politics; Railway Problems and Theorists. G. R. Blanchard. New York, 1880.

From Eliot C. Clarke, Boston:

Paper on Sewerage. Eliot C. Clarke. Boston, 1880.

From Prof. George H. Cook. New Brunswick, N. J.:

Fifteenth Annual Report of Rutger's Scientific School. New Brunswick, 1879.

Annual Report of the State Geologist of New Jersey for 1879. George H. Cook. Trenton, 1879.

From J. James R. Croes, New York:

The best site for the International Exhibition of 1883. J. J. R. Croes, New York, 1880.

From James B. Eads, St. Louis:

Inter-Oceanic Ship Railway. Address of Capt. James B. Eads before the San Francisco Chamber of Commerce, Aug. 11, 1880.

From Engineer Department, U. S. A. Gen. Horatio G. Wright, Chief of Engineers, Washington, D. C.:

Annual Report of Chief of Engineers for 1879. Parts I., II. and III.

Improvement of Harbors at Washington and Georgetown, D. C. S. Thayer Abert.

Proposals for Building Lock N. 6, Great Kanawha River, W. Va. Maj. Wm. P. Craighill.

Specifications for furnishing Piles at Horsetail Bar. Capt. O. H. Ernst.

Specifications, &c., for Improvement of the Osage River between Osage City and Tuscumbia, Mo. Capt. O. H. Ernst.

Specifications relating to the Improvement of St. Johns River, Florida. Gen. Q. A. Gillmore.

Specifications for Improvement of Inside Passage between Fernandina and St. Johns River, Florida. Gen. Q. A. Gillmore.

Specifications for Improvement of the entrance to Cumberland Sound between Georgia and Florida. Gen. Q. A. Gillmore.

Specifications for improvement of the Harbor at Brunswick, Ga. Gen. Q. A. Gillmore.

Specifications for improving Volussia Bar, Florida. Gen. Q. A. Gillmore.

Specifications for U. S. Harbor Improvement, Grand Haven, Mich. Maj. F. Harwood.

Specifications for Improvement Portage Lake, Michigan. Maj. F. Harwood.

Specifications for Harbor Improvement of Muskegon, Mich. Maj. F. Harwood.

Specifications for Harbor Improvement, Ludington, Mich. Maj. F. Harwood.

Specifications for River Improvement, Au Sable, Mich. Maj. F. Harwood.

Specifications for Harbor Improvement of Charlevoix, Mich. Maj. F. Harwood.

Specifications for Improvement of Harbor of Cheboygan, Mich. Maj. F. Harwood.

Specifications for Harbor Improvement, Sebewaing, Mich. Maj. F. Harwood.

Specifications for Improvement of Schuylkill River, Pa. Col. J. N. Macomb.

Specifications for Construction of Piers in Marcus Hook Harbor. Col.. J. N. Macomb.

Specifications for Improvement of Delaware River between Camden and Philadelphia. Col. J. N. Macomb.

Specifications for Improvement of Delaware River at Mifflin Bay. Col. J. W. Macomb.

Specifications for Improvement of Mispillion Creek, Delaware, Col. J. N. Macomb.

Specifications of Improvement of Delaware River near Bordentown, N, J. Col. J. N. Macomb.

Specifications for Improvement of Duck Creek, Delaware. Col. J. N. Macomb.

Specifications for Improvement of Wilmington Harbor, Delaware. Col. J. N. Macomb.

Specifications for U. S. Iron Landing Pier near Lewes, Delaware. Material for Fender System. Col. J. N. Macomb.

Specifications for Removal of Wrecks in Delaware Bay and Delaware Breakwater Harbor. Col. J. N. Macomb.

Specifications for Improvement of Cohansey Creek, N. J. Col. J. N. Macomb.

Specifications for improvement of Schooner Ledge, Delaware River. Col. J. N. Macomb.

Specifications for Improving the Channel at the Mouth of Salem River, N. J, Col. J. N. Macomb.

Advertisement, Specifications and Proposals for Dredging in the Mississippi River near Keithsburg, Ill. Capt. A. Mackenzie.

Specifications, &c., for Constructing Dams and Shore Protections of Brush and Stone at Bar one mile above Winona, Minn. Capt. A. Mackenzie.

Specifications, &c., for constructing Dams and Shore Protections of Brush and Stone near Alexandria, Mo. Capt A. Mackenzie.

Specifications for Dredging in the Harbor of Rock Island, Ill. Capt. A. Mackenzie.

Specifications for Constructing a Dam and Shore Protection of Brush and Stone near Red Wing, Minn. Capt. A. Mackenzie.

Specifications for Constructing a Dam of Stone at Denmark Island, opposite Mundy's Landing, Mo. Capt. A. Mackenzie.

Specifications for Constructing Dams and Shore Protections of Brush and Stone at Bar above Gregory's Landing, Mo. Capt. A. Mackenzie.

Specifications for Constructing Dams and Shore Protections of Brush and Stone at Westport Chute, near Falmuth, Mo. Capt. A. Mackenzie.

Specifications for Constructing Dams and Shore Protections of Brush, Stone and Gravel, near Hannibal, Mo, Capt. A. Mackenzie.

Specification for improvement of Newton Creek, New York. Gen. John Newton.

Proposals for Dredging Currituck Sound, N. C. Capt. Chas. B. Philips.

Proposals for Dredging Harbor at Norfolk, Va. Capt. Chas. B. Phillips.

Specifications for improvement of St. Marys River, Mich. Gen. G. Weitzel.

Second Treatise on the Decrease of Water in Springs, Creeks, and Rivers, contemporaneously with an increase in Height of Floods in cultivated countries. By Sir Gustav Wex. Translated by Gen. G. Weitzel. Washington, 1880.

Specifications for Dredging in Quincy Harbor, Ill.

From Senor F. de Garay, Mexico:

Memoria del Ministerio de Fomento 1865.

Anales de Ministerio de Fomento de la Republica Mexicana. Tomo 111. Mexico, 1880.

Memorial presented to the Congress of Mexico by the Secretary of State on the Public Works, Colonization, Industry and Commerce of Mexico. (Spanish.) Mexico, 1880.

Memorial on the Industry and Commerce of Mexico. Presented to Congress of Mexico by the Secretary of State June 30, 1873. (Spanish.)

From M. Martial Hans, Brussels, Belgium:

Memoire sur les travaux de Canalisation de la Meuse. M. Martial Hans. Brussels, 1880.

From Institution of Civil Engineers, James Forrest, Secretary. London:

Minutes of Proceedings. Vol. LXI.

Abstracts of papers in Foreign Transactions and Periodicals. Vol. LXI. Session 1879–80. Part 3

The Practical Strength of Beams. Benjamin Baker.

The Hydrology of the lower Greensands of Surrey and Hampshire. Joseph Lucas F. G. S.

The Kandahar Railway.

The Amsterdam Ship Canal. Harrison Hayter.

The Seven Stones Light Vessel. James N. Douglas.

From Iron and Steel Institute, London:

Journal of the Institute. No. 1. 1880.

From Robert E. Johnston, London:

Report of the Court of Inquiry and Report of Mr. Rothery upon circumstances attending the Fall of a portion of the Tay Bridge on Dec. 28, 1879.

From Louis H. Knapp, Buffalo, N. Y.:

Eleventh Annual Report of the Buffalo City Water Works. 1880.

From Charles Latimer, Cleveland, O.:

Proceedings of the Road Masters' Meetings of the Atlantic and Great Western R. R. (New York, Penn. & Ohio R, R.) held at Meadville, Pa., Nov, 13, 1879.

From James Lick Trust, Chicago:

Report to the Trustees of the "James Lick Trust" of observations made on Mt Hamilton. S. W., Burnham. Chicago, 1880.

From Massachusetts State Board of Health, Boston, Mass.

First Annual Report on Health, Lunacy and Charity, 1879. Supplement containing the Report and Papers on Public Health. Boston, 1880.

From Massachusets Institute of Technology, Boston:

On the Boston Water Supply. Prof. W. R. Nichols. Boston, 1880.

From John Newman, London:

Note on a New Snow Plough. John Newman. London, 1880.

From Joseph Nimmo, Jr., Chief of Bureau of Statistics, Washington, D. C.:

The Proposed American Inter-Oceanic Canal in its Commercial Aspects. Joseph Nimmo, Jr. Washington, 1880. (Copies for distribution)

From W. Milnor Roberts, Rio de Janeiro, Brazil:

Andre Reboucas. These de Concourso. Rio de Janeiro, 1880.

LIST OF MEMBERS.

ADDITIONS.

MEMBER.

	Date of Election.
BALLARD, ROBERT.....Engineer Northern Divisions Queensland Railways, Rockhampton, Queensland, Australia.....	Sept. 1, 1880.
BARNARD, JOHN F.....Gen. Supt. Kansas City, St. Joseph and Council Bluffs R. R., St. Joseph, Mo.....	" "
BROUGH, REDMOND J....Engineer and Supt. Water Works, Toronto, Canada.....	" "
COMSTOCK, CYRUS B.....Maj. Corps of Engineers, Bvt. Brig. Gen. U. S. A., Detroit, Mich....	" "
FRAZIER, JAMES L.....Res. Eng. Elizabethtown, Lexington, and Big Sandy R. R., Morehead, Ky.....	" "

STANTON, ROBERT B....Engineer's office, Union Pacific Railroad, Denver, Col.....Sept. 1, 1880.
VANCE, HART.....U. S. Ass't Engineer, 1,351 Washington ave., St. Louis, Mo.....July 7, 1880.

ASSOCIATE.

HAMMOND, HENRY B....Pres. Indianapolis, Decatur and Springfield R. R.. 120 Broadway, New York, N. Y.....July 7, 1880.

CHANGES AND CORRECTIONS.

MEMBERS.

DOANE, EDWARD A.....Chief Engineer Meadville Railroad, Box 1,715, Meadville, Pa.
HASELL, BENTLEY D.....Pier 27, N. R., P. O. Box 2,605, New York, N. Y.
KINSLEY, THOMAS P ....231 Broadway, New York, N. Y.
MICHAELIS, OTHO E.....Capt. Ordinance Corps, U. S. A., Frankford Arsenal, Philadelphia, Pa.
MOORE, CHARLES E.....Care of Sweet Mfg. Co., Syracuse, N. Y.
SEARS, ALFRED F .....Chief Engr. Oregonian Railway Co. (Limited), Portland, Oregon.
SEARLES, WILLIAM H...Newburg, N. Y.
WARD, CHARLES D.. ..U. S. Engineer's office, Cleveland, Ohio.
WEIR, FREDERICK C.....Burnet House, Cincinnati, Ohio.

JUNIORS.

CROSBY, BENJAMIN L....Nemaha City, Neb.
HORTON, SANFORD.....Engineer Dept. Southern Pacific R. R., Mescilla, N. M.

RESIGNATION.

ROSS, WILLIAM B.....Junior.....Sept. 23, 1880.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VI.—November, 1880.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

October 20th, 1880.—The Society met at 8 P. M. William H. Paine in the chair.

The subject of wind pressures was discussed by members present.

THE TWENTY-EIGHTH ANNUAL MEETING OF THE SOCIETY,

November 3d, 17th and 18th, 1880.

November 3d, 1880.—The Society met at 10 A. M. William H. Paine in the chair.

The Annual Report of the Board of Direction was presented, ordered printed and submitted to the adjourned meeting on November 17th.

Edward P. North and John G. Van Horne, Members A. S. C. E., were appointed tellers of the ballots to be canvassed this day.

The Annual Reports of the Treasurer and of the Finance Committee were presented, and their consideration postponed.

The Report of the Committee on a Uniform System of Tests of Cement was presented, and its consideration postponed.

On motion, the proposed amendment to Article XXXI. of the Constitution, as printed on page 84, Proceedings, Vol. VI. (October, 1880), was amended by omitting the last clause, it being explained that the

clause was inserted by a clerical error. The amendment, as now proposed, is as follows :

Proposed Amendment to Article XXXI. The Article to read :

The annual contributions shall become due for the ensuing year on the first day of January, and shall be payable in advance. It shall be the duty of the Secretary to notify each member of the amount due for the ensuing year, at the time of giving notice of the Annual Meeting.

The consideration of all the proposed amendments was then postponed to November 17th.

The Report of the Canvass of Suggestions as to place and time for the Thirteenth Annual Convention was presented, and its consideration also postponed.

A recess was taken until 8 P. M.

NOVEMBER 3D, 8 P. M.—The Annual Meeting was resumed. Vice-President Chanute in the chair.

The report of the canvass of ballots for membership was made, and the following were declared elected Juniors of the Society: Thomas Ellis Brown, of New York, and G. Frederick P. Day, of Fitchburg, Mass.

The report of the canvass of ballots for officers was presented, and the following members were declared elected officers of the Society for the ensuing year :

President—JAMES B. FRANCIS.

Vice-Presidents—OCTAVE CHANUTE, ASHBEL WELCH.

Secretary and Librarian—JOHN BOGART.

Treasurer—J. JAMES R. CROES.

Directors—WILLIAM H. PAINE, C. VANDERVOORT SMITH, JOSEPH P. DAVIS, G. BOUSCAREN, D. J. WHITTEMORE.

The Annual Meeting was then adjourned to meet on Wednesday, November 17th, at 10 A. M.

NOVEMBER 17TH, 1880.—The Annual Meeting, adjourned from November 3d, was resumed at 10 A. M. William H. Paine in the chair.

The Secretary announced the details of the proposed arrangements for this and the following day, as shown by the printed programme.

The Annual Report of the Board of Direction was then presented in printed slips and accepted. The Reports of the Treasurer and of the Finance Committee were also presented and accepted. The Report of the Committee on a Uniform System for Tests of Cements was read, placed on file, and the Committee continued.

The Report of the Board of Censors to award the Norman Medal was read, as follows :

"We, the Board of Censors appointed to award the Norman Medal for the year 1880, do award the same to Theodore Cooper, Member A. S.

C. E., author of Paper No. CLXXXVI., "The Use of Steel for Bridges."

JAMES B. FRANCIS.
CHAS. HERMANY.
THOS. C. CLARKE.

The Report of the Canvass of Suggestions as to place for the next Annual Convention was read. These are answers to a circular issued requesting such suggestions. 96 answers were received, as follows:

San Francisco was suggested by	32
Washington " " "	24
New York " " "	8
Long Branch " " "	4
St. Paul " " "	4
Niagara " " "	3
Buffalo " " "	3
Richmond " " "	3
Ithaca (Cornell University) was suggested by	2
Baltimore was suggested by	2
Minneapolis was suggested by	2
Cincinnati " " "	2
Alexandria Bay was suggested by	1
Lake Superior " " "	1
Troy " " "	1
Chicago " " "	1
Providence " " "	1
Saratoga " " "	1
Montreal " " "	1

The subject of a recommendation by this meeting as to the place for the next Convention was discussed, and the following suggestions and remarks as to the places named were made by members present, or read by the Secretary from the answers to the circulars issued on this subject.

As to San Francisco, it was stated that holding the Convention there, and the trip across the continent, would excite a more extended interest in the Society; that excellent opportunity to examine the mineral resources and mining operations would be afforded; that the Pacific Coast contains some of the most peculiar engineering works in this country; that San Francisco itself is one of the most interesting cities of this continent; that while the time occupied might be longer than usual it would be well occupied, and that to many members, such an excursion would be the only opportunity for a visit to the Pacific; that engineers will probably be able to afford such a trip better than for years past; that the Society being National, should take a comprehensive view of

the situation ; that the desire to hold a Convention at San Francisco has been growing and has found expression frequently during several years past ; that, probably, satisfactory arrangements could be made as to the cost of the trip to members.

On the other hand, it was stated that it was understood that while the members of the Society now residing in California would be glad to have a Convention held in San Francisco, yet it was considered that a year or two later than the present would be more desirable, because the Southern railway connections would then be completed, and it was also hoped that the membership of the Society on the Pacific coast would be considerably increased in the meanwhile. It was also said that there were the great objections of the expense of a trip to San Francisco, and the time, little less than a month, that would necessarily be required, and that both these considerations of cost and time would probably prevent the attendance of many members.

On motion it was determined that San Francisco be not recommended as the place for the next Convention.

As to Washington, it was urged that the National Capital possesses many objects of interest to the engineer ; that a Convention there would aid in obtaining National recognition of the Society ; that it is convenient of access for many members ; that it has great local conveniences for convention purposes ; that the conventions should alternate between the East and West or the North and South ; that Congress should be urged to re-establish the work of the commission for testing iron and steel.

On the other hand, it was stated that the regular session of Congress terminated this year on the 4th of March, and that there was no probability of a session being held there this spring or summer ; that it was not desirable that the Convention should be held at Washington at a time when Congress was not in session.

On motion it was determined that Washington be not recommended as the place for the next Convention.

As to St. Paul, it was stated that members resident in the northwest were desirous of having the Society visit that part of the country, but that considering the location of the last two conventions it would probably not be best to go to St. Paul at this time, and that a special invitation would probably be extended to the Society for some future year.

As to Ithaca, N. Y., an invitation was read from Prof. Fuertes, Member A. S. C. E., suggesting that at Cornell University the problems of technical and higher education are being solved under auspices and with tendencies entirely American ; that it is the only American university where all courses of study are placed on an equal footing ; that there is ready access to many interesting places in Central New York, and that the faculty of the university would welcome the Society. It was, however, suggested that there was a question as to the extent of the hotel accommodations.

As to Troy, it was suggested that it was easy of access from all sections ; that many members of the Society who began their professional life there will be glad to visit that city ; that a Convention has never been held in the northern part of the State of New York ; that many places and works of interest could be visited ; large steel works, paper manufactories, &c., are in the vicinity.

As to Providence, it was said that there were excellent hotels and many points of engineering interest ; that it is a great railroad center, only one hour from Boston and close to Newport and many pleasure resorts on Narragansett Bay ; and that also there are in it and its neighborhood many great manufactories.

Another suggestion was made that it might be best for the Society to hold a Convention at some watering place or summer resort ; that such a place could be selected where good accommodations could be secured at reasonable rates, and which should be accessible and interesting ; that a meeting could thus be held without local invitation and thus avoid the imposition of a large tax for entertainment upon the local membership; that at least one experiment of this kind might be desirable.

After the discussion it was on motion determined that a letter ballot be issued, and that this Annual Meeting recommend as the place for the next Convention one of these three points, Niagara Falls, the Thousand Islands or Montreal.

The proposed amendments to the Constitution were then discussed. It was recommended that the following amendments be adopted.

Proposed Amendment to Article XXIII.

Strike out the words "and the Past Presidents of the Society," and insert "such Past Presidents of the Society as shall be at the time Members of the Society and resident in the United States."

Proposed Amendment to Article XXII.

For "first Wednesday in November," read "first day of January."

Proposed Amendment to Article XXX. The Article to read :

The Annual Meeting for the election of officers and hearing the Annual Reports, shall be held on the third Wednesday in January. The Board of Direction shall lay before the meeting a report of the state of the Society, together with a statement by the Treasurer, verified by the Committee on Finance, of the funds of the Society, and the receipts and payments during the year ending on the 31st of December preceding.

Proposed Amendment to Article XXXI. The Article to read :

The annual contributions shall become due for the ensuing year on the first day of January, and shall be payable in advance. It shall be the duty of the Secretary to notify each member of the amount due for the ensuing year, at the time of giving notice of the Annual Meeting.

Proposed Amendment to Article V.

After the words "Annual Meeting of the Society," strike out the words "and shall hold their offices until others are elected," and insert "The term of office shall begin at the close of the Annual Meeting and continue for one year or until other officers are elected."

The following proposed Amendment was then discussed. Article XIX to read :

Proposals for admission to the Society, endorsed by five members as provided in preceding Article, shall be submitted to the Board of Direction at its next meeting. If the applicant is deemed eligible by the Board of Direction, letter ballots shall be issued and these ballots shall be canvassed by the Board of Direction not less than twenty-five days after the date of mailing the ballots. A member voting in the negative on any application, to give with the ballot a written statement of his reasons for such negative vote, which statement he may sign or not as he chooses, but if not signed he must indicate means by which his statement can be verified ; the Board of Direction will then consider the reasons given, and if they are good and sufficient, and if they are deemed to be well founded, the negative vote will be counted and five or more negative votes will exclude the applicant.

Members of the Board of Direction may change their votes to the negative for the reasons shown, after the reasons for giving such vote have been held sufficient ; but such negative vote shall be given openly in the meeting of the Board.

In case of the non-election of any person balloted for, no notice shall be taken thereof in the Society minutes.

Letters favorable to this or a similar amendment were read from Messrs. W. P. Shinn, F. Slataper and T. Egleston.

Mr. W. Crosby presented by letter the following : "I am opposed to the proposed amendment for the following reasons :

1st. It destroys the secrecy of the ballot which was to take the place of the black ball and be equally secret.

2d. It substitutes the judgment of the Board of Direction for that of the individual voting, and, in so doing, takes from the members nearly the last right left them in the managing of the Society's affairs, except that of paying dues.

3d. It calls upon the Board of Direction to reverse a decision already made by it ; a much more trying thing to do, than to come to a just decision in the first instance.

In support of these reasons I advance as follows :

Secrecy is desirable because—

1st. It might often be a great injury to a candidate to relate, even to a limited circle, facts known to be against him, unless it is considered that, like a woman's secret, which is better kept the more possess it; five members added to the whole number in the Board of Direction, can better keep those facts to themselves than could the same five members without the assistance of the Board.

2d. The secrecy of the ballot is desirable even when the unworthiness of the candidate is known to many, because most men, not ambitious of martyrdom, do not wish to be known as opposing the admission of any one, whatever their feelings may be, but prefer to let the responsibility be a little indefinite.

The proposed plan gives to a bare majority of a quorum of the Board of Direction, four persons, the power to override the wishes of a great number, or even of all of the members outside of that quorum, and to admit to membership any man, however objectionable, that small majority may see fit.

Since there is practically no way of getting rid of an obnoxious member, so long as he pays his dues, if we would preserve a high standard, too great care cannot be exercised in the admission, and therefore members should be free to vote effectively in this matter, and this seems an undesirable bestowal of power, particularly when there is such a diversity of opinion as to the conditions that candidates should fulfill, some persons who have been very much in the Board of Direction, being much less strict in that than many members outside of that Board."

The following discussion then took place :

George W. Dresser.—I desire to offer an amendment to this proposed amendment to the Constitution. It seems to me that this point can be made against this amendment as proposed. The members may, or may not send in, in writing, signed or unsigned, their reasons for their negative vote. If they do, the Board can have that information to act upon, and, of course, the votes of the Board will be sufficient to defeat the election of the man. The common course of the thing would be that the members would say, I don't care to write out my reasons, but I will simply vote against that man, and get four others to do so, and we will defeat his election. The simplest way to rectify this matter is to put the responsibility of a recommendation for election, not for ballot, but for election, upon the Board of Direction. They are in a position to enquire and obtain whatever information may be necessary for them to form a judgment, and if the matter is so adjusted that their recommendation is for election, they will take very great care to inquire and inform themselves about each proposed candidate and not give a negative recommendation but a positive one. If they simply do not know anything either for or against the man, they will post themselves, and for that reason I would suggest the propriety of placing the responsibility upon the Board, who are bound to see that no detriment shall come to the Society, and in that light there is nothing more important for them to consider than the admission of members. The second point I would like to make is this : that the affirmative votes count for nothing, and it is only the negative votes that throw the man out. It is simply within the power of any five members to prevent the admission of a single member to the society by simply striking their pen through the word yes on the ballot as sent out. Therefore I would require that there shall be more than five members necessary to reject a candidate for membership of this Society after a recommendation of the Board of Direction for election has been made.

To bring this to a point, I would recommend that in the fourth line of the present amendment, as printed, the words "deemed eligible" be stricken out, and the words "recommended for election" be inserted in their place, so that clause would read : "If the applicant is recommended for election by the Board of Direction, letter ballots," &c. That leaves the letter ballot as it stands in the proposed amendment, and that change

being made, leaves the rest of the proposed amendment useless, and I would scratch out all that follows, beginning with "a member voting in the negative," &c., and would insert there: "An affirmative vote of at least four-fifths of all the votes cast shall be necessary for an election." This places the matter upon the same basis as the Institution of Civil Engineers in England. They require four-fifths of the votes cast to elect a member, and I think the success of that institution is sufficient guarantee for us to adopt the same rule.

It seems to me that this will place the matter in a very simple form; that it will eradicate the difficulty that we have been laboring under, and it will put the matter where no man can assume to say to us that we manage the affairs of a professional Society as though it were a social

The great objection to the present system is apparent, I think, to every one. It is well known to many members of the Society that gentlemen of high standing, and occupying high positions—men who are a credit and an honor to the profession, and would be men of influence and importance to us as a body if they were members of the Society—have been rejected as members by barely five votes, and that this thing may be done again. Any man who occupies a high position must find it necessary at times to bring some of the younger members up with a round turn occasionally. It may have been, perhaps, without any intention of being unkind, but it must work a hardship to these younger gentlemen. But finally this man who has done this thing comes up as an applicant for membership. This young man meets one or two of his friends: "Here we have got him; we can sock it to him now; we will make him smart." That is the way the thing works practically. Shall we ask all who want to join to submit themselves to the risk of any such treatment? It seems to me that an affirmative vote of four-fifths ought to be ample, and I would move this amendment, sir, to the amendment.

This was seconded.

W. R. Hutton.—As I understand the amendment, as printed, only those votes can be counted which are sustained by the objection.

The Secretary.—That is not as suggested by Mr. Dresser.

Mr. Katte.—I think there is a radical defect in this amendment as printed. I don't see how it will be proper for the Board to change any vote. If a man votes no, where does the Board of Direction derive the power to throw that ballot out?

I think we must change that proposition entirely. Otherwise I think the amendment is a very good one, indeed. The four-fifths rule in London has been found to work well for a long time. There can hardly be any doubt that our present rule has done us a great deal of injury. This whole discussion has arisen from a case in point. We have undoubtedly lost a very valuable member—a gentleman who stands

high in the profession and in the estimation of his friends. Now, I think that when a gentleman of that character is rejected by this Society by five negative votes it is nearly approaching a scandal upon this Society. For that reason I concur in the amendment offered by Mr. Dresser.

The meeting was then adjourned to 8:30 P. M.

NOVEMBER 17TH, 8:30 P. M.—The session of the Annual Meeting was resumed, Vice-President Ashbel Welch in the chair.

MR. WELCH.—Gentlemen, I take this occasion to thank the Society for the unexpected honor done to me by electing me to one of its high places.

The consideration of the amendment proposed to Article XIX of the Constitution was continued.

The annual meeting then, by vote, adopted the following amendment to the proposed amendment to Article XIX of the Constitution and recommended its passage as thus amended. Article XIX to read :

Proposals for admission to the Society, endorsed by five members as provided in the preceding Article, shall be submitted to the Board of Direction at its next meeting. If the applicant is recommended for election by the Board of Direction, letter ballots shall be issued and these ballots shall be canvassed by the Board of Direction not less than twenty-five days after the date of mailing the ballots.

An affirmative vote of at least four-fifths of all the votes cast shall be necessary for an election.

In case of the non-election of any person balloted for, no notice shall be taken thereof in the Society minutes.

The following proposed Amendment to the By-Laws was then brought up. Proposed by F. COLLINGWOOD, Member A. S. C. E., and seconded by G. LEVERICH, Member A. S. C. E.

An amendment to the By-Laws, to take the place of Section 24.

SECTION 24. Any member entitled to vote for officers of the Society, may, before the third Wednesday of November, in any year, nominate such officers for the ensuing year, by presenting the names of such nominees in writing over his own signature, in a sealed envelope, addressed to the Board of Direction, and endorsed, "Nominations for Officers."

The Board of Direction or those of its members present at a meeting of the Board, to be held on said third Wednesday of November, for this purpose, shall prepare a list in alphabetical order, under the title of each office, of all the persons thus nominated and eligible to the respective offices, together with the class of membership of each as to whether resident or non-resident.

Within one week thereafter, the Secretary shall mail such list, with a copy of this section, to all members of whatever class.

Members qualified to vote for officers may do so by striking from or adding to this list, and return the same as their ballots, but each ballot shall contain not more than one name for President, one for Secretary, one for Treasurer, and one for Librarian, two names for Vice-President and five names for Directors. Of these, one Vice-President, the Secretary, the Treasurer, the Librarian and three Directors must be resident members.

The vote shall be by letter, in like manner as prescribed for admission to membership, and be canvassed at the Annual Meeting next succeeding. The presiding officer shall appoint three or more tellers for the canvass, who shall reject all ballots not in conformity with the Constitution and By-Laws, and report the result in full to the meeting in writing, such report to be preserved by the Secretary for reference.

The nominee for any office receiving the greatest number of legal ballots shall be declared elected to that office.

If, in any case, in consequence of two or more nominees receiving an equal number of votes, there is no election of a particular officer, the members present, who are entitled to vote, shall elect such officer by plurality ballot, from those nominees receiving the highest number of votes.

On motion it was determined that the letter ballot on this proposed amendment to the By-Laws be issued with a brief statement of the argument for and against the change proposed, such arguments to be prepared by the proposers and by any opposer there may be to it.

The Committee on Gauging Streams then presented a report through J. J. R. Croes, chairman, including certain tables and documents furnished by A. Fteley, Member A. S. C. E.

The report was discussed by Messrs A. Welch, J. P. Davis, F. Collingwood, C. E Emery, G. W. Dresser, S. L. Smedley, J. E. Hilgard, T. C. Clarke, A. G. Compton, O. Chanute and J. J. R. Croes.

A paper by Mr. Frederick S Odell, C. E., describing the sewerage recently put in at Memphis, Tenn., was then read and discussed by Messrs. E. S. Philbrick, F. Collingwood, J. J. R. Croes, A. P. Boller, G. W. Dresser, R. Cartwright, S. L. Smedley, W. E. Worthen and J. Bogart.

The Annual Meeting then adjourned.

In addition to the meetings, the record of which is above given, visits and excursions were made to the points named in the programme arranged by the resident members for this occasion. This programme, which was carried out as printed, was as follows :

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Twenty-Eighth Annual Meeting,

New York, November 17th and 18th, 1880.

The Annual Meeting adjourned from November 3d, will be resumed on Wednesday, November 17th.

The following arrangements have been made for that and the succeeding day :

Wednesday, November 17th.

10 A. M.—Annual meeting at Society House, No. 104 East 20th street. Business Meeting.—Reading of Annual Reports, Discussion on Reports, and on proposed Amendments to the Constitution and By-Laws, and other business. Meeting to adjourn at 12.30 P. M.

1 P. M.—Meet at the Engineer's Office of the New York and Brooklyn Bridge, corner of Pearl and Cherry streets, New York—(Franklin Square station of East-side Elevated Railroads.) Lunch will be served at 1 o'clock. The plans and structure of the bridge will then be examined, under the guidance of the engineers in charge.

3 P. M.—Those who do not desire to spend the rest of the afternoon in the examination of the bridge, will elect one of the following excursions, each of which will be in charge of resident members :

(A.) A steamer will leave the Bridge Pier at 3 P. M., and passing down the East River and around the Battery, the party will inspect the terminal arrangements of railroads at Jersey City, and proceed to the Elevator of the Erie Railway, and afterwards the works of the Hudson River Tunnel.

(B.) A party in company with resident members will visit the buildings of the Western Union Telegraph Company, the Equitable Life Insurance Co., and the exhibition of the electric light.

(C.) Those who desire to make more detailed examinations of the Bridge, will have facilities for doing so during the rest of the afternoon.

8. P. M.—Meeting at Society House.

THURSDAY, NOVEMBER 18TH.

10 A. M.—A special train will leave on the up-town track of the Elevated Railroad at Ninth street and Third avenue, at 10 A. M., sharp ; proceed to and inspect shops at 99th street and Third avenue. Leave shops at 10.50, arrive at terminus, 129th street and Third avenue, at 11. Proceed on foot to termius of Second Avenue Elevated Railroad at 127th street and Second avenue, and leave there at 11.15 ; pass over Second Avenue Railroad to the Battery. Leave the Battery at 12 ; inspect arrangements for dispatching trains at Rector street, and proceed *via* Sixth and Eighth Avenue Elevated Railroads to 125th street and Eighth avenue.

1 P. M.—Visit and inspection of the apparatus of the Prall System for Heating and Cooking by Hot Water, at 125th street and Eighth avenue. Lunch will be served at the same place.

After lunch the members will visit either of the following points of interest, the parties for each will be conducted by resident members :

The Armory of the Seventh Regiment.

The pumping station, reservoirs and aqueduct of the Croton Water Department.

Some of the illuminating gas works of the city.

The Egyptian Obelisk, its proposed site, and the Central Park.

The excursions may be joined at any of the points mentioned above. The presentation of a member's ticket will be required, which may be obtained from the Secretary of the Society.

8 P M.—A reception will be given by the resident members at Pinard's, No. 6 East 15th street ; to be followed by a supper. Special tickets for this will be required, which may be obtained from the Secretary of the Society.

P. S.—A visit to the Fair of the American Institute may be made at

any time. Members desiring to make this visit will be supplied with tickets by the Secretary.

The members of the Society present during the meeting were as follows:

Edward R. Andrews, John W. Bacon, George S. Baxter, H. D. Blunden, John Bogart, A. P. Boller, D. Bontecou, T. E. Browne, Robt. Cartwright, O. Chanute, T. C. Clarke, F. Collingwood, A. G. Compton, G. B. Cornell, M. Coryell, J. J. R. Croes, D. W. Cunningham, J. H. Cunningham, Joseph P. Davis, P. P. Dickinson, E. B. Dorsey, George W. Dresser, T. Egleston, S. Clarence Ellis, Theo. G. Ellis, C. E. Emery, Albert Fink, Clark Fisher, R. Fletcher, M. N. Forney, B. Godwin, Geo. S. Greene, Jr., M. S. Greenough, G. Thomas Hall, Wm. G. Hamilton, S. Haslett, Charles H. Haswell, Clemens Herschel, J. E. Hilgard, W. R. Hutton, Walter Katté, William E. Kelley, Thomas P. Kinsley, E. D. Leavitt, Jr., G. Leverich, Thomas J. Long, Charles Macdonald, Wm. W. Maclay, C. S. Maurice, Arthur Macy, C. C. Martin, C. L. McAlpine, G. W. McNulty, A. G. Menocal, C. H. Myers, Chas. Neilson, Geo. B. Nicholson, F. O. Norton, E. B. Noyes, Wm. H. Paine, E. S. Philbrick, F. C. Prindle, Jos. R. Richards, S. H. Shreve, S. L. Smedley, C. V. Smith, T. Guilford Smith, R. P. Staats, Cook Talcott, Geo. C. Tingley, S. Towle, J. G. Van Horne, E. Vanderpool, E. B. Van Winkle, W. W. Walker, C. G. Weir, A. Welch, H. M. Wightman, Wm. H. Wiley and Wm. E. Worthen.

OF THE BOARD OF DIRECTION.

October 1st, 1880.—Arrangements for the Annual Meeting were considered, and a recommendation adopted that such meeting be adjourned on November 3d and continued on November 17th and 18th. The report of the Nominating Committee was received, and action was taken thereon as provided by the By-Laws. Appropriations were made.

November 1st, 1880.—Applications were considered. The Secretary presented his Annual Report to the Board. The Annual Report of the Board of Direction was perfected.

November 10th, 1880.—The Board of Direction for the year beginning November 3d, 1880, met and organized. The following Standing Committees were appointed:

On Finance, { William H. Paine, C. Vandervoort Smith, Joseph P. Davis.

On Library, { J. James R. Croes, O. Chanute, Ashbel Welch.

Applications were considered. Appropriations were made.

ANNUAL REPORT

OF THE BOARD OF DIRECTION FOR THE YEAR ENDING, NOVEMBER 3, 1880.

Presented and accepted at the Annual Meeting of that date.

The Board of Direction presents the following report for the term from November 5, 1879, to November 3, 1880 :

On November 5, 1879, the membership in the Society was :

Honorary members, resident,	2	Non-resident....	4	Total....		6	
Corresponding members...		"	3	"		3	
Members, resident.....	116	"	347	"	463		
Associates "	5	"	13	"	18		
Juniors "	8	"	46	"	54		
	—		—			—	535
Making, resident.....	131	Non-resident...	413				—
Total.....							544
Fellows, 66 of whom 10 members and 1 Honorary Member are included above, leaving.....							55
							—
Total connected with the Society November 5, 1879.....							599

At the present time the membership is :

Honorary members, resident....	3	Non-resident....	9	Total...		12	
Corresponding members.....		"	3	" ...		3	
Members, resident.....	114	"	359	"	473		
Associates, "	6	"	 14	"	20		
Juniors. "	6	"	 42	"	48		
	—		—			—	541
Making, resident.....	129	Non-resident....	427				—
Total.....							556
Fellows 66 of whom 10 members and 1 honorary member are included above, leaving.....							55
							—
Total connected with the Society November 3, 1880.....							611

The additions during the past year to the several classes of Society membership have been :

Honorary members	6
Members qualified	58
Associates qualified	8
Juniors qualified	5
Total additions to the several classes of membership	77

The decrease during the year in the several classes of membership has been :

Members	Died, 8	Resigned, 3		11
Associates	Died, 1	Resigned, 0	Transferred to member, 1	2
Juniors	Died, 0	Resigned, 1	Transferred to member, 5; " to Associate, 1	7
Totals	Deaths, 9	Resignations, 4	Transfers, 7	20

There has also been a decrease during the year of the following numbers whose membership has ceased under the provisions of Article XXVII of the Constitution:

Members, 37.....Associates, 4.....Juniors, 4.....Total, 45

There has thus been an addition of 77 to the various classes of membership, and a loss by deaths, resignations and transfers of 20, making the actual net additions during the year 57 in number.

The loss of 45 members for non-payment of dues makes the apparent increase for the year only twelve. It is, however, proper to state that this loss is entirely of those who have contributed nothing to the Society for a number of years, and the continuance of whose names upon the list of members has been in many cases a mere formality.

The addition of 77, or, not counting the seven transfers from one class to another, the actual addition of 70 new members to the Society, is a gratifying increase over the number of yearly additions, and has not been equalled for many past years of its history, in fact not since the period of its general reorganization. It is the belief of this Board that the rate of increase may easily be made greater by a very moderate amount of personal effort on the part of present members. A suggestion to this effect was issued in a circular note sent to members during the past year, from which the following is quoted : "The American Society of Civil Engineers now contains nearly six hundred members. In order to increase its usefulness, while maintaining its high standard of requirements, it desires to draw to itself a larger proportion of those engaged in engineering and kindred pursuits, who are estimated to number about 8 000 in this country. It is suggested that you may be able to propose the names of worthy persons for New Members, Associates, Juniors and Fellows." Each addition to the list of members actually increases in a large ratio

the benefit of the Society to each individual, and enlarges its opportunities as regards the profession of engineering.

A number of applications for membership has been received from engineers residing beyond the limits of the United States, and an increasing interest in the Society has been manifested in various ways, both in this country and elsewhere.

Since the last report of this Board there has been added to the list of honorary members of the Society the names of six distinguished engineers, each one of whom has been, in the opinion of the members of the Board, and of the past presidents of the Society, a gentleman of acknowledged eminence in some branch of engineering, as specified in our constitution. Two of these are resident in the United States, General H. G. Wright, the Chief of Engineers of the United States Army, and Mr. John Ericsson, the distinguished man who, during half a century, has made so many additions to the theory and practice of civil and mechanical engineering. The four other honorary members added during the year, Sir John Hawkshaw, Baron M. M. Von Weber, Mr. E. Malézieux, and Mr. Justin Dirks are representative engineers of England, Germany, France and Holland.

On November 5, 1879, there were, as stated in the last annual report, 13 proposals pending ; 65 proposals have been received during the year ; 58 candidates have been elected members, of whom 5 were transferred from Juniors and 1 from Associate ; 8 candidates have been elected Associates, of whom 1 was transferred from Junior ; 5 candidates have been elected Juniors.

58 persons have, during the year, qualified as Members, of whom 1 was elected last year ; 8 have qualified as Associates ; 5 have qualified as Juniors ; 1 candidate elected during the year as Member has not yet qualified ; there are are 4 proposals now pending.

Twenty-four meetings of the Society were held during the year, one of which was the Twelfth Annual Convention, all the sessions of the Convention, including the business meeting, being counted as one meeting of the Society. Meetings have been held on the first and third Wednesdays of each month, except that there were no meetings in August, and but one in July. Three meetings of the Society were held in January and three in February.

Sixteen meetings of the Board of Direction have been held during the year.

One of the Society meetings in February was held at the Theatre of the Union League Club on the occasion of the discussion on the subject of Inter-Oceanic Canals. At this meetings M. de Lesseps presented his views and was followed by Messrs. Dirks, Dauzat, and other engineers. The experiment of holding public meetings on the occasion of the discussion of subjects of general public interest proved in this instance very successful, and it is hoped that opportunities for meetings of

such a character will frequently occur and be taken advantage of. A healthy renewal of interest in the society may result both on the part of its members and of the public generally.

At the meeting of the Society in May last it was determined that the library and conversation rooms at the Society House should thereafter be open each Wednesday evening instead of Thursday evening. This change has proved very acceptable. Members now find the rooms lighted, and either a formal meeting of the Society or an opportunity for conversation and the consultation of books, papers, and periodicals on the evenings of every Wednesday of the year.

The Twelfth Annual Convention was held at St. Louis, Mo. May 25th, 26th, 27th, and 28th, 1880.

Fully detailed reports have been published in our Proceedings, of that Convention, of the excursions and entertainments connected with it, and of the great hospitality given the Society and its guests by citizens of St. Louis, both members of the Society and many others interested in its work. The great advantage to the Society, and to the profession of engineering, from such meetings of engineers, from all parts of the country, is more and more evident with each annual convention.

In the arrangements for the present Annual Meeting, suggested by this Board, and approved at the meeting of the Society of October 6th, it has been the purpose to provide for the more convenient attendance of non-resident members, and for more perfected arrangements for their entertainment than has been attempted generally on the occasion of annual meetings. These having occurred heretofore on the first Wednesday in November, a date which has been found inconvenient for many members, and each annual meeting continuing but one day, and that being necessarily largely devoted to business discussions, there has not been developed such an interest in the meetings as to attract many members to them. The proposed adjournment of this meeting to the middle of the month, and the arrangements in progress under charge of a committee to make the meeting attractive, will, it is believed, add to the interest heretofore attaching to these occasions, and, it is hoped, will increase the attendance upon them in the future.

The answers to a circular issued to the Society, requesting suggestions as to the place and time for the next convention, will be submitted at this meeting.

Reports made during the year have been as follows:

By the Board of Direction. The Annual Report for the year.
By the Finance Committee. 2 reports.
By the Library Committee. A report on the Circulation of the Books of the Library.
By the Treasurer. His annual report, and also frequent statements to the Board.
By the Secretary. Monthly reports to the Board.
By the Committee on Tests of American Iron, Steel, and other Metals. 1 report.
By the Comm ttee on Gauging of Streams. 2 reports.
By the Committee on Methods of Nominations. 1 report.

By the Committee on Uniform System of Tests of Cement. 1 report.

By the Committee on Preservation of Timber. 1 report.

The Treasurer's Report and the Report of the Finance Committee will be submitted at this meeting.

By the Committee on Paris Exhibit. 1 report, and the committee discharged.

By the Centennial Commission. 1 report, and the committee discharged.

By the Committee on Permanent Quarters for the Society. 1 report, the committee discharged, and a new committee appointed.

Reports will be expected at this meeting from the Committees on Tests of Iron and Steel; on Gauging of Streams; on a Uniform System of Tests of Cement; on Experiments on Wind Pressures, and on the Preservation of Timber.

The Library has been increased during the year by the following additions:

Number of books bound	93
" " unbound	187
" pamphlets	404
" maps and plans	70
" photographs	18
" drawings, specifications, models and specimens	72

These do not include magazines and papers contributed to the Society by publishers, or received in exchange for the Transactions, a list of which is given in an appendix to this report.

The present state of the Library is about as follows:

Books and pamphlets	8,738
Manuscripts	105
Maps, plans, drawings, charts, photographs and engravings	2,114
Models and specimens	230

Previous to this year, the funds of the Society were not in such a condition as to warrant, in the opinion of the Board, any greater expenditure upon the Library, than was requisite to its proper preservation and arrangement. With the establishment of a financial management, which now gives the Board a fair assurance of the income to be depended upon for a current year, it has been possible to push forward the work of making and printing a library catalogue, which shall give to our members information of what the library contains. As suggested in the Report of the Library Committee, presented and accepted at the annual meeting one year ago (printed in Proceedings for November, 1879), such a catalogue will be of value for members desiring to consult books on special subjects, and also will, by showing what the library lacks, be serviceable in securing additions to-

wards perfecting its collection. The railroad section has been completely arranged, catalogued, and the catalogue printed. The very large amount of labor and care and time absolutely necessary in perfecting the proofs, is almost inconceivable to those who have not had similar work to do. The final revision, however, is now in press, the catalogue of other sections of the library are also being perfected, and during the coming year it is hoped may be completed and issued.

The attention of members is asked to the fact that they can render important assistance in making the library more complete by forwarding such books, reports and pamphlets as they are willing to give to the Society, and by making suggestions concerning books to be added and the management of the library.

As also suggested in the report of the Library Committee referred to above, the Board, at the beginning of the present year, authorized the Secretary to arrange for such use of the library as might be possible by the members of the Society who could not personally consult its volumes. A circular note was consequently issued to the following purport :

"In order that members, more particularly non-residents, may better avail themselves of the facilities of the Society in New York, the Secretary is authorized by the Board of Direction to state, that he will assist in procuring such profesional information as may be asked for.

If members will address him concerning data required by them, reference to engineering books or works, the elucidation of particular subjects, or other information which they may desire, he will consult the library of the Society, or members who are experts upon the subject presented, and endeavor to furnish the information desired, or to indicate where it is to be found.

So far as practicable such services will be rendered gratuitously. When however they involve expense for copying drawings or extracts from books and papers, or the surrender of considerable time by the Secretary or the members whom he may consult, a charge will be made therefor, but in such cases an approximate estimate of the cost will be submitted to the member applying for the information, and his instructions asked for before incurring the expense."

The Secretary has been able, in the way thus arranged, to give to a number of members professional information from the sources indicated.

The subject of a provision of more permanent quarters for the Society than the present house, which is rented from year to year, was, at the meeting of the Society in February last, referred to a committee consisting of the President, Secretary and Standing Committee on Finance. This committee issued a circular suggesting a subscription to a loan secured by bonds which it was thought might enable the Society to secure a suitable house by purchase and pay for the property during a term of years. A number of replies were received but the result was not such as to warrant the purchase of a house at that time. The considera-

tion of this matter will, doubtless, be resumed during the ensuing year, and should receive earnest attention.

The following note addressed by the Secretary in February of the present year to all members of the Society, explains itself:

"The records of the Society are very incomplete as regards the professional life of its members. Except in recent cases the applications for membership give but meagre details of the Engineering Works of the applicants, and in few instances has sufficient additional information been furnished to keep up a proper record.

I am requested therefore, by the Board of Direction, to ask you to transmit a condensed statement of your professional life, including the character of the works upon which you have been engaged, giving dates and full titles of the organizations under which they were prosecuted. Please add also your full name and the date and place of birth. These statements are asked for the purpose of perfecting the records of the Society, and furnishing hereafter information concerning the lives and works of American Engineers."

The Board regrets that the replies to this note have been but few, and it desires to impress upon all the members the importance of completing this record which can, of course, only be perfected by the individual replies of each member of the Society.

Applications for the recommendation of engineers to fill various positions have been occasionally made to the Secretary and other officers of the Society, and the subject of some systematic provision for an official attention to such applications was considered by the Board early during the current year. It was determined to authorize the Secretary to keep a record of the members of the Society, who may inform him that they are open to new engagements, together with a statement (furnished by such members) of their previous engagements and experience, and of the positions and compensations desired. To any person desiring the services of an engineer the record of those who would be apt to fill the requirement is to be sent. The intervention of the Secretary is intended only to put into communication employers and members desiring engagements. No charge is made and no responsibility is assumed.

Circulars to this effect were issued to members of the Society and to a number of managers of public works. There are now on the record the statements of several members desiring engagements, and quite a number of applications for the records have been received from persons desiring the services of engineers. Several important appointments have resulted from the correspondence inaugurated by this means but to be entirely successful there should be a much greater number of members' names and statements put on record. The Secretary can only send those which are formally presented.

A number of proposed amendments to the Constitution and By-laws have been submitted for debate at the present Annual Meeting. These have been already issued to members of the Society.

The Board of Censors to award the Norman Medal for the past year, Messrs. James B. Francis, Thomas C. Clarke and Charles Hermany, are expected to report at this meeting.

The financial affairs of the Society are in excellent condition, as will be seen from the reports of the Treasurer and of the Finance Committe. The general business measures referred to in the last Annual Report of the Board of Direction have been carried out with gratifying results. These measures include the action then determined upon with reference to arrears of dues. There had been carried upon the register of the Society for a number of years the names of persons who contributed nothing to its support, and who have during the past year permitted their names to be dropped from the rolls. This reduces, apparently, the increase of membership to a small figure, although there have been actually 77 members qualified in the various classes of membership during the year. There is not the slightest doubt felt by the Board of Direction that these business methods in reference to the financial conduct of the Society will continue to be of the greatest value in its future progress.

The Transactions of the Society have been regularly issued monthly during the past year. An appeal is earnestly made to the members to contribute papers, discussions or even brief notes upon practical engineering works which come under their observation. It is much desired to include in the Transactions of this Society records of the progress of engineering in America. The past volumes are becoming valuable books of reference, and if the members of the Society will co-operate with the officers in this respect the worth of the Transactions will be greatly increased.

The loss to the Society by the death of eight Members and one Associate during the year has been as follows :

Thomas A. Emmet, elected Member November 5, 1852, who died January 12, 1880.

John C. Thompson, elected Member May 18, 1870, who died January 17, 1880.

I. M. St. John, elected Member July 14. 1871, who died April 7, 1880.

Max Hjortsberg, elected Member November 22, 1872, who died May 16, 1880.

George W. Edge, elected Member March 4, 1874, who died January 1, 1880.

Thomas S. Hardee, elected Member April 4, 1877, who died May 21, 1880.

James A. Hayward, elected Member September 5, 1877, who died August 13, 1880.

William H. Greenwood, elected Member March 3, 1880, who died August 30, 1880.

Arthur L. Ford, elected Associate November 6, 1872, who died May 30, 1880.

In all nine, of whom memoirs have been published or are in preparation.

Respectfully submitted,

JOHN BOGART,
Secretary.

REPORT OF THE FINANCE COMMITTEE.

PRESENTED AT THE ANNUAL MEETING,

NOVEMBER 3D, 1880.

To the President and Directors of the American Society of Civil Engineers:

GENTLEMEN,—The Finance Committee would respectfully report that on entering upon their duties they carefully examined and compared the accounts of the Secretary and Treasurer, including all of the entries and vouchers for the year ending November 5th, 1879, and found them correct and corresponding with the annual reports of these officers.

The committee also examined the assets of the Society, personally inspecting all securities held by the Treasurer, and found them as reported.

During the year just closed the committee has audited all bills presented, and has in no instance allowed any expenditure to exceed the appropriations made by the Board of Direction for such objects.

That while the expenditures for the printing of circulars and postage upon the same, together with the costs of the arranging and catalogueing of the library, now in progress, have been unusually large, the amounts so expended were, in our opinion, wisely appropriated, as the results have been to widen our field of usefulness, increase our membership and replenish our treasury.

There has been a large and valuable accession to our list of members during the past year, which is not apparent from the fact that there has also been dropped from the rolls the names of many delinquents, who have been an incubus upon our progress, and served to misrepresent our real strength; the actual number admitted to active membership exceeds that of any former years since the years in which the Society was reorganized.

The income of the Society has more largely exceeded its expenditures than in any former year.

The books of the Secretary and Treasurer have been so systematically and intelligibly kept, and so promptly posted up to date, that the verification of the accounts of the year just closed is already accomplished, and the committee can endorse the reports of these officers as correct, and would respectfully refer the members to these reports for all the

items and amounts of income, expenditures, assets and debts of the Society.

And, in conclusion, would congratulate the officers and members upon the fact that this past has been the most prosperous year of the existence of this organization, and that we have evidently entered upon an era of increasing prosperity.

Very respectfully submitted,

W. H. Paine,
Chrm. Finance Com.

REPORT OF THE COMMITTEE ON A UNIFORM SYSTEM FOR TESTS OF CEMENTS.

Presented at the Annual Meeting.

November 3, 1880.

To the American Society of Civil Engineers:

The committee appointed by your Society to devise a uniform system for testing cements, report progress as follows, viz.:

Soon after being notified of their appointment the Chairman of said committee addressed a communication to each member, suggesting topics for consideration relating to the duty expected of them.

There has been received by the Chairman of said committee valuable papers relating to the testing of cement, from the following parties: J. B. White & Sons, London, England; translations of the German official regulations for uniformly delivering and testing cement, from F. W. Lehnartz, member of the Society; also the same in German from Charles O. Gleim, corresponding member of the Society at Cologne, the receipt of which contributions has been duly acknowledged. There has also been received by the Chairman, from an unknown source, a copy of the papers upon Portland Cement, by John Grant, M. I. C. E.; Maj. Gen. H. Y. D. Scott, C. B. R. E., Assoc. Inst. C. E.; and Gilbert R. Redgrave, Assoc. Inst. C. E.; and E. A. Bernays, M. Inst. C. E., entitled: I.—"The manufacture and testing of Portland Cement;" II.—"Portland Cement Concrete, and some of its applications;" III.—"Portland Cement; its nature, tests, and uses;" being papers read before and published by the Institution of Civil Engineers, London, England.

All of these papers have an important bearing upon the subject in hand, and will undoubtedly aid us in formulating a uniform system of tests.

It is the intention of the committee to commence an interchange of views upon the subject during the coming winter months, during which

time the papers referred to will be laid before the members of the committee for their consideration, and they will endeavor to complete their duty on or before the date of the next annual convention of the Society.

We would suggest that the Society endeavor to procure for such of the committee as have not received them copies of the publication of the Institution of Civil Engineers last referred to above.

Respectfully submitted,

D. J. WHITTEMORE, *Chairman.*

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
SIMPSON, GEORGE H.	City Engineer, Terre Haute, Ind	Oct. 6, 1880.
WALKER, WILLIAM W.	Gen. Supt. St. Louis, Hannibal and Keokuk R.R., Hannibal, Mo	" "

JUNIORS.

BROWN, THOMAS E., JR.	Asst. Engineer Manhattan Railway Co., 337 W. Thirty-fourth Street, New York City, N. Y.	Nov. 3, 1880.
DAY, G. FREDERIC P.	Asst. Engineer Fitchburg R.R., Fitchburg, Mass	" "

CHANGES AND CORRECTIONS.

MEMBERS.

ALLEN, C. FRANK ..... Engineer's Office A. T. & S. F. R.R., Las Vegas, N. M.

CANFIELD, EDWARD ..... New York, Lake Erie and Western R. R. Co., Buffalo, N. Y.

DOANE, EDWIN A. ..... Chief Engineer, Rome, Watertown and Ogdensburg R.R., Lewiston, N. Y.

DUNCKLEE, JOHN B. ..... 1010 Mass. Ave., Washington, D. C.

FINK, RUDOLPH..... .. .Ferro Carril Mexico Central, Ciudad de Mexico, Republic of Mexico.
HASLETT, SULLIVAN.....5 Cortland St., Room 77, New York City.
HILL, JOHN W.....Glenn Building, Room 21, Cor 5th and Race Streets, Cincinnati, Ohio.
MORSS. FOSTER.....Chief Engineer Shenandoah Valley R.R., Hagerstown, Md.
OSGOOD, JOSEPH O.....Chief Engineer California Southern R.R., San Diego, Cal.
RICHARDS, CHARLES B ...Supt. Southwark Foundry and Machine Co., 430 Washington Ave., Philadelphia, Pa.
RICHARDSON, HENRY B...Chief State Engineer, New Orleans, La.
SHINN, WILLIAM P.....Pittsburgh, Pa.
WELLMAN, DAVID W.....1351 Washington Ave., St. Louis, Mo.

JUNIORS.

HAINES, CASPAR W .....Cheltenham, Montgomery Co., Pa.
PEGRAM, GEORGE H.....Edgmoor Iron Co., Wilmington, Del.

RESIGNATIONS.

KENNEDY, JAMES C.....Junior..... .....Nov. 1, 1880.
KNAPP, GEORGE O..... " ....Oct. 23, 1880.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VI.—December, 1880.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

DECEMBER 1ST, 1880.—The Society met at 8 P. M. William E. Worthen in the Chair.

Ballots were canvassed, and Lyman Bridges, of San Francisco, Cal.; James Foster Crowell, of Elizabeth City, N. C., and Francis Ingram Palmer, of New York, were declared elected Members.

A paper by J. W. Putnam, Associate A. S. C. E., on the "Renewal of Foundation, and the Transfer of a Lighthouse in Pascagoulas Harbor," was read by the Secretary and discussed by Messrs. J. P. Davis, Kinsley, Morison and Worthen.

Samples of piles destroyed by the teredo, and of others protected by creosote, were presented and examined.

DECEMBER 15TH, 1880.—The Society met at 8 P. M. Vice-President Welch in the Chair.

A paper by C. Shaler Smith, Member A. S. C. E., on "Wind Strains in Bridges," was read by the Secretary, and discussed by Messrs. T. C. Clarke, Hayes and Welch.

A photograph and description of an arch erected at Cohoes, N. Y., with centering posts founded on cast iron pots filled with sand, was presented by D. H. Van Auken, C. E., through W. E. Worthen, Member

A. S. C. E., and was discussed by Messrs. Bogart, T. C. Clarke, J. P. Davis and Welch.

OF THE BOARD OF DIRECTION.

DECEMBER 8TH, 1880.—Applications for membership were considered.

The question of a provision for more permanent quarters for the Society was discussed.

DECEMBER 22D, 1880.—The mode of issuing ballots for proposed amendments to the Constitution was considered and determined.

Action was taken upon the subject of a proposed fund for securing more permanent quarters for the Society.

DECEMBER 29TH, 1880.—Applications were considered. The following resolution was adopted: *Whereas*, The Society has now outgrown its house accommodations and cannot well secure adequate quarters unless the same be specially planned for its needs, therefore *Resolved*, that in order to secure a more permanent home for the Society, the Board of Direction will inaugurate the collection of a Building Fund, and the Secretary be instructed to issue a circular in the name of the Board to members and to other persons interested in the advancement of engineering, asking for contributions to such fund.

Resolved, That all such contributions shall be duly acknowledged by printing lists of the same from time to time, in the proceedings of the Society.

Resolved, That the names of all those persons who may subscribe $100 or more shall regularly be printed to accompany future lists of members of the Society, under the head of "Subscribers to the Building Fund," and they shall be entitled to receive regularly, for life, one copy of the Transactions of the Society for each $100 subscribed by them; such copy to be in addition to those which they may be entitled to as Members or Fellows.

The form of circular to be issued under the above resolutions was then considered, and adopted as follows:

JANUARY 1st, 1881.

The American Society of Civil Engineers has completely outgrown its present house accommodations, and its usefulness is impeded by want of adequate lodgings. It needs a more permanent home, properly arranged for its use, where the business of the Society and that of non-resident members on a visit to New York can be carried on. This should comprise in addition to offices, writing and consultation rooms, a lecture room in which meetings will be held, and especially a library, where its 9,000 volumes and pamphlets of engineering literature, its models, drawings, maps and pictures, can be conveniently arranged for reference, be reasonably secure against fire, and have provision for constant enlargement.

A few members of the Society, appreciating these needs, have taken steps to organize a building association. They have subscribed part of the money required, have begun negotiations for some lots in desirable locations in New York City, and have proposed to the Society that it shall join them in erecting a building, of which the lower story should be devoted to the uses of the Society, and the upper floors be finished into private apartments or flats for the members of the building association.

Whatever may be the outcome of this plan—and the Board of Direction will only commit itself to it, if upon due examination it is found to answer every needful requirement of security and convenience—the first requisite step to provide for the necessities of the Society is to raise an adequate sum of money.

The Society now owns a Fellowship Fund of some $9,000 ; but this is a trust specifically pledged to the publication of the Transactions of the Society, and cannot be diverted to other purposes. The Board of Direction, therefore, proposes to collect a Building Fund, which it desires to reach $25,000 or $30,000, for the purpose of securing a more permanent home for the Society upon the most desirable basis. This Fund to be placed in a special trust, under proper security, until enough is collected, and plans are decided upon.

A contribution to this fund will be gratefully accepted from you ; it is hoped that every member of the Society will give something according to his means.

To provide for such other voluntary contributions as may be offered, a copy of this circular will also be sent to engineers who are not members of the Society, to the Managers of Public Works, and to other gentlemen interested in the advancement of engineering, in the hope that they will avail themselves of this method of becoming connected with the Society, by enrolling their names upon its books. By a resolution of the Board of Direction, all contributions to the Building Fund are to be acknowledged from time to time, by printing lists of the same in the monthly proceedings of the Society, and in addition to this, the names of all those who may subscribe $100 or more are to be regularly enrolled and published in future lists of the Society, under the head of Subscribers to the Building Fund, and they shall be entitled to receive one copy of the monthly publications comprising all papers and transactions of the Society, regularly, for life, for each $100 subscribed by them, such copies to be in addition to those which they may be already entitled to, if they are Members or Fellows.

As negotiations are pending, it is important that we should know soon what can be done. Will you be good enough, therefore, to answer at once on the enclosed blank, by filling in the amount which you are willing to contribute, payable one-half the 1st of March, and one-half the 1st of July, 1881, and return the same in the envelope addressed to the Secretary.

We specially request an answer from every member, even from those who are not in position to subscribe at present, so that the Board of Direction may know how much can be raised.

THE BOARD OF DIRECTION.

JAMES B. FRANCIS,
President.

O. CHANUTE,
ASHBEL WELCH.
Vice-Presidents.

JOHN BOGART,
Secretary,

J. JAMES R. CROES,
Treasurer.

WILLIAM H. PAINE,
C. VANDERVOORT SMITH,
JOSEPH P. DAVIS,
G. BOUSCAREN,
D. J. WHITTEMORE,
Directors.

REPORT OF THE TREASURER

FOR THE YEAR ENDING NOVEMBER 3D, 1880.

Presented at the Twenty-eighth Annual Meeting.

RECEIPTS.

Balance on hand November 5th, 1879		$697 06
Entrance fees		1 850 00
Current dues—from 88 Resident Members	$2 151 28	
" " 262 Non-resident Members	3 697 43	
" " 5 Resident Associates	67 50	
" " 13 Non-resident Associates	120 00	
" " 2 Resident Juniors	30 00	
" " 33 Non-resident Juniors	300 20	
		6 366 41

Past dues—from 8 Resident Members	$350 00	
" " 18 Non-resident Members	440 00	
" " 1 Resident Junior	15 00	
" " 2 Non-resident Juniors	30 00	
		$835 00
Dues for year beginning Nov. 3d, 1880:		
From 25 Resident Members	$625 00	
" 99 Non-resident members	1 461 13	
" 3 Non-resident Associates	30 00	
" 13 Non-resident Juniors	130 00	
		2 246 13
Sales of Publications		299 80
Certificates of Membership		82 50
Miscellaneous		8 00
Interest on Fellowship Fund Bonds	$560 00	
" Norman Medal Fund	105 00	
" Savings Bank Deposit	37 40	
" Railroad Stock	82 80	
		785 20
		$13 170 10

DISBURSEMENTS.

Rent	$1 600 00
Janitor, House Supplies, Fuel, Furniture, Water and Gas	955 88
Library	385 53
Publications	2 364 06
Insurance	47 12
Postage	649 14
Salaries	3 000 00
Stationery and Printing	558 77
Annual Meeting and Convention	150 65
Certificates of Membership	55 10
Other expenditures	132 26
Transferred to Savings Bank Deposit	37 40
Norman Medal	65 80
Balance on hand	3 168 39
	$13 170 10

The funds of the Society are as follows, par values being stated :

Fellowship Fund :			
80 Subscriptions		$8 150 00	
Accumulated interest, Nov. 5, 1879		776 43	
Interest received during past year		597 40	
		$9 523 83	
Expended from fund during year for publications		560 00	
		$8 963 83	
Present condition : 80 Subscriptions	$8 150 00		
Accumulated interest	813 83		
			$8 963 83
The Fellowship Fund is invested as follows :			
8 Bonds Jersey City Water Loan		$8 000 00	
Deposit in Seamen's Bank for Savings		963 83	
Norman Medal Fund :			
1 Certificate Croton Aqueduct Stock, New York City			1 000 00
General Investment :			
10 Shares New York Central and Hudson River R. R. Stock		1 000 00	
1 Consolidated Certificate New York Central and Hudson River R. R. Stock		35 00	
			1 035 00

J. JAMES R. CROES,
Treasurer.

LIST OF PUBLICATIONS AND PAPERS RECEIVED FOR LIBRARY.

APPENDIX TO ANNUAL REPORT OF BOARD OF DIRECTION, NOVEMBER 3D, 1880.

The following papers are contributed to the Society, or are received in exchange for Transactions.

American Architect and Building News	Weekly	Boston.
American Engineer	Monthly	Chicago.
American Gas Light Journal	Semi-Monthly	New York.
American Machinist	Weekly	"

Annales des Travaux Publics	Monthly	Paris.
Army and Navy Journal	Weekly	New York.
Builder	"	London.
Building and Engineering News	"	"
Bulletin American Iron and Steel Association	Semi-Monthly	Philadelphia.
Bulletin du Canal Interocéanique	Semi-monthly	Paris
Commissioner of Patents Journal	Semi-Weekly	London.
Deutsche Bauzeitung	Weekly	Berlin.
Engineer	"	London.
Engineering	"	"
Engineering and Mining Journal	"	New York.
Engineering News	"	"
Iron	"	London.
Iron Age	"	New York.
Journal of Artillery and Military Engineering	Monthly	Vienna.
" of Society of Arts	Weekly	London.
Manufacturer and Builder	Monthly	New York.
Manufacturer and Iron World	Weekly	Pittsburgh.
Monthly Record of Scientific Literature	Monthly	New York.
National Car Builder	"	"
Railroad Gazette	Weekly	"
Railway Age	"	Chicago.
Railway Reporter	Monthly	Pittsburgh.
Railway Review	Weekly	Chicago,
Railway World	"	Philadelphia.
Repertorium der Technischen Literatur		Leipsig.
Revue Générale des Chemins de Fer	Monthly	Paris.
Sanitary Engineer	Semi-Monthly	New York.
Scientific American	Weekly	"
Tehnic Tidskrift	Monthly	Stockholm.
Telegraph Journal and Electric Review	Semi-Monthly	London.
The Locomotive	Monthly	Hartford.
Universal Engineer	Weekly	London
Van Nostrand's Magazine	Monthly	New York.
Zeitschrift fur Baukunde	Quarterly	Munich.

The following are subscribed for :

American Bookseller	Semi-Monthly	New York.
American Catalogue	"	"
American Library Journal	Monthly	"
Bookseller	"	London.
Publishers' Weekly	Weekly	New York.
U. S. Official Postal Guide	Monthly	Boston.

The Society has received during the year, in exchange for the "Transactions" official publications of the following associations in many instances for preceding years :

Aeronautical Society of Great Britain	London.
Academy of Sciences	Washington.
American Chemical Society	New York.
American Gas Light Association	"
American Institute of Architects	"
American Institute of Mining Engineers	Easton.
American Iron and Steel Association	Philadelphia.
Annales des Ponts et Chausèes	Paris.
Argentine Scientific Society	Buenos Ayres.
Association of Civil Engineers	Lisbon.

Austrian Society of Engineers and Architects (Two Publications).....Vienna.
Boston Public Library.....Boston.
Boston Society of Civil Engineers..... "
Civil Engineers' Club of Cleveland.....Cleveland.
Die Administration der "Mittheilungen".....Vienna.
Engineers' Club of Philadelphia .....Philadelphia.
Engineers' Club of St. Louis.....St. Louis.
Engineer Department, U. S. A.....Washington.
Engineers Society, Western Pennsylvania.....Pittsburgh.
Essayons' Club, Corps of Engineers, U. S. A.....Willetts Point.
Franklin Institute, Journal.....Philadelphia.
Imperial School.....Moscow.
Imperial Technic Society of Russia.....St. Petersburg.
Imperial University.....Tokio.
Institution of Civil Engineers.....London.
" " of Ireland.....Dublin.
" of Engineers and Shipbuilders of Scotland .....Glasgow.
" of Mechanical Engineers.....London.
Iron and Steel Institute..... "
Massachusetts Institute of Technology.....Boston.
McGill University, Department of Science.....Montreal.
Mechanics' Institute.....San Francisco.
Midland Institute Mining, Civil and Mechanical Engineers .....Barnsley.
New York Meteorological Observatory.....New York.
North of England Institute of Mining and Mechanical Engineers.....Newcastle-on-Tyne.
Pi Eta Scientific Society.....Troy.
Royal United Service Institution.....London.
School of Mines, Columbia College.....New York.
Smithsonian Institution.....Washington.
Society of Arts.....London.
Society of Civil Engineers.....Paris.
Society of Engineers.....London.
Society of Engineers and Architects of Hungary.....Budapest.
" " " of Saxony.....Dresden.
" " " .....Hannover.
Stevens Institute of Technology.....Hoboken.
Swedish Society of Engineers.....Stockholm.
Thayer Scientific School, Dartmouth College.....Hanover.
Thomasson Civil Engineering College, Indian Engineering.....Roorkee.
United States Coast Survey.....Washington.
" Light House Board..... "
" Naval Institute.....Annapolis.
" Naval Observatory.....Washington.
" Ordnance Department..... "
University of Michigan.....Ann Arbor.
Western Society of Engineers.....Chicago.

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LIST OF MEMBERS.

ADDITIONS.

HONORARY MEMBERS.

	Date of Election.
HAWKSHAW, SIR JOHN....33 Great George Street, London, England.....	Nov. 3, 1880.
MALEZIEUX, EMILE,.....Inspector General *Ponts et Chaussees*, Paris, France.....	" "

MEMBERS.

BRIDGES, LYMAN.....Chief Engineer California Central Railway, 702 Market St., San Francisco, Cal.....Dec. 1, 1880.
CROWELL, J. FOSTER.....Chief Engineer Elizabeth City and Norfolk Railway, Elizabeth City, N. C. " "
PALMER, FRANCIS J.....68 Wall St., N. Y. City.....,..... " "

CHANGES AND CORRECTIONS.

MEMBERS.

DICKINSON, P. P.....237 Broadway, New York City, N. Y.
FRAZIER, JAMES L.....Alabama Great Southern Railroad Co., Chattanooga, Tenn.
FTELEY, A.....Chief Asst. City Engineer, Boston, Mass.
GOLAY, PHILIP.....307 Court St., Cincinnati, Ohio.
KINSLEY, THOMAS P..... 72 Myrtle Ave., Brooklyn, N. Y.
LOW, GORHAM P., Jr.....Engineer's Office New York and New England Railroad, Boston, Mass.
NEWMAN, ROBERT M.....Cheboygan, Mich.
NICHOLS, AURIN B.....Gen. Man. Reynoldsville Mining and Mfg. Co., Reynoldsville, Pa.
NICOLLS, WILLIAM J.....Chief Engineer Danville, Mocksville and Southwestern R. R., Leaksville, N. C.
PARKHURST, HENRY W....1st Asst. Engineer Bismarck Bridge, Bismarck, Dakota.
POST, LEVI W.....Care of Wilkins, Post & Co., Atlanta, Ga.
STRIEDINGER, JULIUS H..Chief Engineer Magdalena River Improvement, Barranquilla, U. S. of Colombia.
SWEET, ELNATHAN, Jr....New York, Ontario and Western Railway, West Point, N. Y,

JUNIORS.

CROSBY, BENJAMIN L.....P. O. Box, 194, Nebraska City, Neb.
LUCAS, D. JONES.....Div. Engineer, Philadelphia and Long Branch Railroad, Toms River, N. J.
STAHLBERG, ALBERT J....Asst. Engineer Oregonian Pacific Railway (Limited), Portland, Oregon.

DEATH.

WORTHINGTON, HENRY R. Elected Member January 5, 1876. Died December 17, 1880.

ERRATA.

Proceedings, Vol. VI., page 96. November, 1880.

12th line from bottom, for "objection," read "Direction," so as to read "only those votes can be counted which are sustained by the Direction."

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